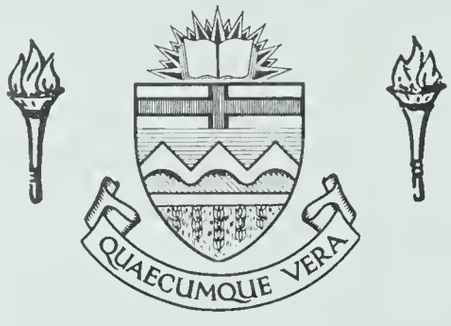

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FACTORS AFFECTING THE LOCATION OF ENERGY INTENSIVE INDUSTRIES

BY

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled FACTORS AFFECTING THE LOCATION OF ENERGY INTENSIVE INDUSTRIES submitted by Douglas H. Younie in partial fulfilment of the requirements for the degree of Master of Arts.

ABSTRACT

Although the use of energy resources is pervasive throughout the economy they are important to the economic considerations of only a small number of industries. For firms in these few industries regional differentials in the price of energy inputs can influence the choice of location.

Two statistical tests, the rank correlation and the location quotient, were employed in an attempt to relate the location of energy intensive industries to the location of low cost energy resources. Data limitations were such that firm conclusions could be arrived at for only the pulp and paper industry, several mining industries and the industrial chemicals industry. Low cost electricity to be used as motive power is important to the pulp and paper industry and to mining industries when choosing between two or more alternative sites. The availability of petroleum products to be used as a feedstock is important to the industrial organic chemicals industry.

The linkages of the energy resources and of the energy intensive industries were observed. The energy resources are all heavily forward linked to the rest of the economy but their properties are such that their forward linkages are not necessarily confined to the areas from which the energy resources originate. Two energy intensive industries, industrial chemicals and petroleum and coal products have

heavy forward and heavy backward linkages.

It is evident that an industrial policy of a province possessing energy resources should consider both the locational characteristics and the linkage effects of energy intensive industries.

ACKNOWLEDGEMENTS

Appreciation is extended to Professor S. E. Drugge for suggesting the topic and for acting as my supervisor during the writing of this thesis. His numerous helpful suggestions enabled me to bring some semblance of order to an otherwise disorganized paper. Thanks are also due to Mrs. Hester Hardwick for an excellent typing job.

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CHAPTER I

INTRODUCTION

The objective of this thesis is to evaluate the importance of energy resources as determinants of industrial location, with special emphasis to be placed on the Canadian situation. The scarcity of literature regarding the subject as well as the growing concerns of our southern neighbor as to how best to exploit "continental" energy resources implies that the usefulness of this study may be other than minute.

If it can be determined that for some major industries the existence of cheap energy at a particular geographic location is of considerable importance in causing that industry to locate near that point in space, then a policy of large scale exportation of that particular energy resource could have the effect of driving up the domestic price of that energy resource and might neutralize or totally negate the locational pull that existed to attract the industry to that location in the first place. Policies of influencing industrial location by granting subsidies or tax concessions to firms which will locate in specified areas could also reduce the importance of energy as a determinant of industrial location. Likewise, a policy that allows imports of energy resources can have the effect of reducing interregional price differentials within the country for those particular energy resources, thereby weakening the locational attraction

that might exist in certain regions of the country.

In brief, the locational decisions of firms are influenced by three major factors. One is the existence of a plentiful supply of cheap labor. A second reason for locating at a particular spot is to minimize total transportation outlays. The third factor influencing location is the existence of particular natural resources. It may be economically impractical to locate at other than the site of an immobile natural resource. A prime example might be a mine site. The firm has no choice but to locate at that site although it may have the choice of two or more different sites.

If energy is mentioned at all in the literature on location theory it is regarded as another natural resource and no particular attention is paid to its precise role in the locational considerations of the firm. Energy sources can be used either for feedstock or for fuel. For some fuels such as natural gas or crude oil the energy resource may be employed as a fuel or as an input into the production process. When energy resources are used as fuels they can, in many cases, be regarded as substitutes for one another. When they are used as a feedstock they are not substitutable and in that case significant regional price differentials may play a role in firms' locational decisions.

This study will be concerned primarily with the energy resources of coal, crude oil and its refined products, natural gas, and electricity. Much of the coal used for industrial purposes in Canada is imported from the United States. Natural gas and petroleum products

are natural resources which are discovered and processed in Canada. Electricity is an energy resource generated either by hydro power or by thermal generation. Thermal power requires either coal, fuel oil or natural gas as a necessary fuel.

It will be the object of this thesis to determine the importance of these resources to particular industries. From available data it will be determined which are the energy intensive industries from the point of view of the cost of total inputs. The prices of energy inputs will be observed for the different regions of Canada and from that tests will be made to determine if these price differentials bear any relation to the level of activity of these energy intensive industries in the various regions. It will also be determined if these industries are key industries from the point of view of forward and backward linkages.

CHAPTER II

A GENERAL THEORY OF LOCATION

In order to determine the role, if any, that energy plays in influencing industrial location it is useful, indeed necessary, first to consider in some detail the accepted theory of why firms locate where they do.

This analysis of location theory will deal with the factors which influence a firm's choice of location under the following seven headings: 1) transportation costs, 2) labor costs, 3) agglomerative and deglomerative factors, 4) other cost factors, 5) market factors, 6) the availability of skilled labor, taxation, local authority cooperation and personal factors, 7) energy factors.[1] I will not attempt to analyze the simultaneous influence of these factors on the decision of where to locate, but instead will deal with the individual influence of each factor. In essence it will be a partial rather than a general equilibrium approach to location theory.

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[1]For much of this chapter I will rely to a considerable extent upon a Master's thesis as follows: Ingrid A. Bryan, An Economic Critique of Swedish Industrial Policy, 1968 (unpublished; Faculty of Graduate Studies, University of Alberta).

Transportation Costs

Traditionally, transportation costs have received more attention in the literature on location theory than have the other locational factors. There are several reasons for this. That for many industries transportation plays an important role is a readily acceptable fact and is an easy concept to grasp. Irregularities and inconsistencies in the pricing structures of transporting goods can be assumed away into an ideal weight such as a ton mile. In essence, most transport costs can be transformed into an ideal weight that is a function of weight and distance. As well, the fact that when many of the earlier theories of location were developed transportation was perhaps the most important aspect to be considered is another reason for much of the emphasis given to this factor.

One of the earliest classics in the field of location theory was written by Alfred Weber.[2] He states the implicit assumption that is made in most of the later literature on the subject when he writes: "Locational factors are .... advantages in cost".[3] The objective of location theory then, is to find "those elements of cost which differ according to the location of the productive process".[4]

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[2]Alfred Weber, Alfred Weber's Theory of Location of Industries, translated with an Introduction and notes by Carl J. Friedrich, (Chicago: University of Chicago Press, 1929).

[3]Ibid., p. 25

[4]Ibid., p. 25

Weber felt that certain factors could be expressed in terms of transportation costs. For example, "different price levels of different deposits of the same material operate as if one had to overcome different distances for these deposits from these deposits to the place of manufacturing".[5] This means that of two deposits the same distance from a manufacturing site, the richer deposit would be treated as if it were further away from the manufacturing site than would a deposit whose price was lower per unit of weight. This type of analysis was easily adaptable to the railroad freight structure of Germany at the turn of the century.

In much the same manner, variations in transport rates among different railroad lines could also be taken into consideration. For a line charging a higher rate than the average it would simply be assumed that the rate corresponded to the average but that the distance to be covered was proportionately longer.

For rates which vary not just with the weight of the good to be shipped but also with its bulk, its value, its perishability, and the fact that less than a full carload, for example a half carload, may be occupied by the goods to be shipped, Weber introduced the concept of ideal weight. To paraphrase Weber's explanation, if a higher rate per unit to be shipped is charged to goods because they are shipped in smaller quantities than are goods which occupy a full carload, then those goods occupying less than a full carload

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[5] Ibid., p. 34.

can be regarded as having an "ideal weight" in addition to the real weight.[6] For example, if the rate charged to shipments of less than full carloads is one and one half times that charged to full carloads, then those shipments occupying less than a full carload could be regarded as having an additional "ideal weight" of 50 per cent of their real rate.

As the above shows, Weber had managed to transform most of the peculiarities and inconsistencies of freight rate structures of the railroad systems of early twentieth century Germany into the two basic elements of transportation costs, weight and distance.

From these basic theories, Weber developed two units of measurement to determine which is the best location from the point of view of minimizing transportation costs. These are the material index and the locational weight. The material index is the ratio of the weight of localized raw materials to the weight of the final product. Should the material index exceed one, it can be implied that the localized raw materials used are weight losing during the production process. This implies that production should take place at the site of the localized raw materials since at this location less weight will have to be shipped than if the plant was located at the market place. It should be noted, however, that because final goods are usually more expensive to ship than are raw materials and if the freight charges differ substantially between raw materials and finished goods then the material index may lose much of its meaning

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[6] Ibid., pp. 44-45.

since it could actually be that a firm would reduce total transport costs by locating at the market place rather than at the raw material source. Bryan, in her thesis, cites an empirical study which illustrated that the material index was not a very powerful tool of analysis.[7] The study showed that while all industries located at a raw material site had a material index exceeding one, not all industries with a material index of more than one located near the raw material source.

With respect to a material index of less than one, possibly because of the addition of some ubiquitous raw material located at the market place to cut down on the total weight being shipped, it would be expected that location would take place at the market place since this is where total transport costs would be minimized. The only possible exception would be if the localized raw material source was very concentrated and the market place was widely dispersed.

The second index introduced by Weber was the locational weight, the measure of the total weight to be moved per unit of product weight. This is obviously related to the material index. If the material index is less than one, then the locational weight is less than two. In such a case, production would be expected to occur at the market place. Of course, a similar association applies when the material index exceeds one.

It should be noted in passing that this concept has implicitly

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[7]Bryan, op. cit., p. 35

assumed that there is only one stage of production and that only one raw material that is not ubiquitous is used in the production process. If these assumptions are relaxed the same type of analysis will still be carried out but it generally requires some type of geometrical analysis, using lines, triangles, and polygons.

An example of a locational figure in the form of a triangle would be two localized raw material sources and one market, any other raw materials being ubiquitous. Each of these locations would comprise a corner of the triangle, each of the sides of this triangle representing the cost of transporting the raw material in question to the place of consumption or to the site of the other raw material. Given the weight of the final product and the weights of the raw materials the point where total transport costs are minimized can be determined. Conceptually, the principle behind the locational figures is quite simple. The pull of the respective weights at the corners of the figures will determine the point of minimum transport costs.[8]

Isard observed some fundamental weaknesses in Weber's analysis. One of these concerned transport rate structures where rates were less than proportional to distance.[9] Weber attempted to take this problem of when the marginal cost of a ton mile differs from the

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[8]For a detailed explanation of the workings of the locational figures, see Weber, pp. 53-71 and 227-252, or Bryan, pp. 31-33.

[9]Walter Isard, Location and Space Economy (New York: John Wiley and Sons and the Technology Press of the Massachusetts Institute of Technology), p. 108.

average cost into account by varying the lengths of the sides of the locational figure in accordance with the decreasing rate scale rather than with the geographic distance. Isard, however, points out a dilemma that exists. He says, "..how can we know how much to shorten the distance of any corner of the locational polygon from the given site of production until the actual location of the production site is determined; whilst on the other hand the very location of the production site is dependent upon the relative distances between the various corners of the locational polygon?".[10] In essence, he seems to be saying that in this case a general equilibrium approach is more applicable than is a partial equilibrium approach.

With regards to the recognition that transport costs do not always vary proportionally with distance, Isard turns to the problem of loading and terminal charges. In many cases such charges comprise a significant portion of total transport costs. Therefore, many industries can minimize their total transportation costs by locating near terminal and loading sites. Thus, it is not by accident that a great many industrialized centers in North America are located near port facilities.

Thus far we have examined some of the theoretical ideas of what makes a location the least cost location with respect to the price of transport. Transportation costs depend on the weight of the goods to be shipped as well as the distance to be covered.

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[10] Ibid., p. 109.

Shipments of less than one carload or of perishable goods or bulky goods increase transportation costs as do loading and terminal charges. Mathematical and geometrical solutions for finding the point of minimum transportation costs exist. Concepts such as the material index have more theoretical than practical value. For example, there may be production costs such as large quantities of energy inputs which have no direct effect on the weight of the final product but could reduce transportation to a relatively small proportion of the total costs to the firm. The same could be said for the costs of labor. Also, the fact that improved transportation technology and loading facilities lead to reduced transportation costs tends to make the location factor of transport less important than might otherwise be the case. In many cases the transportation cost differentials between alternative production sites may be insignificant enough that other locational factors determine the location of the plant.

Labor Costs

In addition to transportation costs, another substantial factor influencing industrial location is the cost of labor. By the costs of labor will be meant total wages and salaries paid out by the individual firms. In many cases an industry will locate in an area where there is an adequate supply of cheap labor in order to minimize its total costs. Probably the most widely recognized industry which is oriented to cheap labor is the textile industry. In the United

States it gradually moved to the South after having been established in the New England area because the cost of labor was sufficiently lower in the former region to offset all other cost disadvantages associated with location in the South. This is in accordance with any common sense theory of location. It does not mean, however, that an industry will always choose a low cost labor location. In many instances the low cost labor is not sufficiently skilled or productive enough to perform adequately to meet the production standards of the firm and hence it is nonsensical to locate in an area just because cheap labor is available. Thus, with respect to labor orientation of location the reservation must be made that the industry locates where there is a sufficient supply of adequately skilled workers, not just where there is a large supply of available workers.

In an attempt to measure the impact of labor costs on industrial location, Weber developed the concept of isodapanes.[11] An isodapane is a curve drawn around the point of minimum transportation cost. For every point on the particular isodapane, the amount by which transportation costs exceed the minimum transportation cost is the same. The critical isodapane is that curve which connects the points where the excess of transport costs over the minimum equals the savings in labor costs which could be achieved by locating on that isodapane rather than at the point of minimum transportation cost. For a location where the increase in transportation costs exceeds the savings in labor costs that would result, it would

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[11]Weber, op. cit., pp. 103-106.

be foolish for the firm to locate at that point. To quote Weber: "A location can be moved from the point of minimum transportation costs to a more favorable labor location only if the savings in the cost of labor which this new place makes possible are larger than the additional costs of transportation which it involves".[12]

This theoretical concept of isodapanes thus shows how a rational firm, considering only transportation and labor costs would choose its location based on the varying costs of these two factors at different points.

Weber also introduced two other concepts in an attempt to measure the extent to which the influence of labor determines industrial location. These were the Index of Labor Costs and the Coefficient of Labor.

The Index of Labor Costs is the cost of labor per unit, say per ton, of the final good which would have to be moved due to movement away from the minimum transportation cost site. The higher the Index of Labor Costs, the more beneficial it would be for the firm to locate its plant where labor costs are lower than at the point of minimum transportation costs. It should be noted, however, that this Index of Labor Costs may be inaccurate in that the weight of the final good may not adequately reflect the increase in transportation costs because of locating at other than the minimum transportation cost location. An example of this is the case where weight losing raw materials are used in the production process.

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[12] Ibid., p. 103.

To circumvent this problem, Weber resorted to the second concept, that of the Labor Coefficient. This Labor Coefficient is the ratio of the Index of Labor Costs to the Locational Weight. It is the labor cost per ton of product divided by the tons of weight to be moved per ton of product. From this it is quite clear that the higher the Labor Coefficient, the more likely it is that the firm will choose a site of lower labor costs than that which exists at the point of minimum transportation costs.

Agglomerative and Deglomerative Factors

Analysis of transportation and labor costs gradually evolves into a study of agglomerative and deglomerative factors of location theory.

Isard classifies agglomeration factors into three main categories:

1) Large Scale Economies within a firm, consequent upon the enlargement of the firm's scale of production at one point.
2) Localization Economies for all firms in a single industry at a single location, consequent upon the enlargement of the total output of that industry at that location.
3) Urbanization Economies for all firms in all industries at a single location, consequent upon the enlargement of the total economic size (population, income, output, or wealth) of that location, for all industries taken together.[13]

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[13] Isard, op. cit., p. 172.

The first classification, large scale economies, can be adequately analyzed from a microeconomic framework. If a market is served from two or more points within the market area, it could well be that the firm would encounter economies of scale sufficient to cover the increased transportation costs involved from producing from one large plant within the area. If such is indeed the case, then the production of the firm will tend to agglomerate at that point. The question of just where agglomeration may take place can be answered by observing Weber's isodapanes.[14] Given two or more points where production occurs to minimize total transportation costs, for any point in the area where two or more critical isodapanes overlap (i.e. within the common segments of the critical isodapanes) every such point is a possible point of agglomeration since at any of these points total costs of production will be lower than if it took place at the several points which minimized transportation costs. The actual point of agglomeration will be "that one of several possible points of agglomeration which has the lowest transportation costs in relation to the total agglomerated output".[15] If, on the other hand, the critical isodapanes do not overlap, there is a tendency not to agglomerate but rather to deglomerate.

The second classification of agglomeration, localization economies, refers to those cases where several firms within an industry

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[14]Weber, op. cit., pp. 138-139.

[15]Ibid., p. 138

locate in one place. An example of this may be the oil industry in Edmonton where several large firms are located, giving rise to the existence of a number of smaller firms to service these large firms and, therefore, indirectly lowering the total costs to these firms, which would otherwise have to perform these services themselves at a higher cost than that which they would incur by paying the service industry. Thus, such external economies may give rise to agglomeration of several firms of the same industry in one location.

The third classification, urbanization economies, is a result of the growth of the entire urban area, rather than the growth of one firm or one industry as in the previous two cases. There may arise in a large urban area economies of scale in the supply of certain public goods such as education and health services as well as water and sewage facilities. In addition, the larger population of an urban area implies the existence of a large market for finished goods and many firms will desire to locate near the market. This is an example of agglomeration due to urbanization. There may also exist diseconomies, both pecuniary and non-pecuniary, which result from urbanization. To the extent that these diseconomies lead to rising costs for the firm, such as increased transportation costs, these diseconomies may lead to the deglomeration of an urban area.

Other Cost Factors

In addition to transportation, labor and agglomeration, several other factors have an influence on industrial location. One of these

factors is the availability of energy resources, the factor which will be analyzed in detail in the remaining parts of this paper. For those industries which are energy intensive, this factor is of significance.

The availability of capital may also significantly influence the firm's choice of location. Here, reference is being made to capital equipment rather than to monetary capital, the latter of which can usually be regarded as being quite mobile. A firm with an already large investment in relatively immobile capital equipment is likely to expand its facilities at its given location rather than to locate elsewhere in the immediate area. Also, a heavy investment in capital equipment may make a firm reluctant to relocate even though the other factors of location suggest that this is desirable. A firm without previous investment in capital equipment will not suffer from these necessary cost inhibitions.

Another cost factor is rent, although its influence would likely affect locational decisions within rather than between regions.

Market Factors

The market factors of location put particular emphasis on the demand side, unlike Weber's analysis which concentrates principally on the supply factors which influence industrial location. Lösch, in particular, criticizes Weber's approach which implicitly assumes that revenues are constant. With that assumption profit maximization will occur at the point or points where total

costs are minimized. Lösch examines market factors and their effect on optimal location.[16] By adding market factors to the analysis, one is no longer able to determine the point of optimal location algebraically or geometrically.

To illustrate this problem that emerges when one looks at both the supply and demand sides of the problem, it might be useful to follow the analysis done by Bryan in her work on Swedish location policy.[17] It was assumed that consumers were evenly spread out over a large market area. Several firms produce a relatively homogeneous product, thus implying that consumers are indifferent between the output of the different firms. The restrictive assumption that procurement and processing costs are the same, regardless of location, is made. Producers are willing and capable of selling to the entire market. Transportation costs are absorbed by the consumer.

If demand for the product is inelastic, then the firm's revenues are unaffected no matter what its location. If, however, demand is quite elastic, then producers will spread themselves throughout the market such that distribution costs (which are absorbed by the consumers) will be minimized. A pattern of regionally bounded markets will appear, their size and shape depending upon the distribution of population, the number of producers and the systems of

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[16] August Lösch, The Economics of Location, translated by William H. Woglom, (New Haven: Yale University Press, 1954), pp. 27-28.

[17] Bryan, op. cit., pp. 47-49.

transportation available. Thus, the importance of the market factor can be summed up by stating that by paying attention to the demand side, industrial location is given an additional pull towards the market than if just transportation and labor factors were analyzed.

The Availability of Skilled Labor, Taxation, Local Authority Cooperation and Personal Factors

Several factors, in addition to those already mentioned, have an influence on the locational decisions of the firm. Some, such as personal factors, may be very arbitrary and cannot be explained in any theoretical manner. Others may be the result of conscious policies of various levels of government. Others, such as the availability of skilled labor, may have some theoretical basis from which an attempt to quantify the influence of that specific factor can be made.

As mentioned, skilled labor is one of these additional factors. To some extent, skilled labor can be considered as being mobile. It is necessary only to consider the cost of attracting the necessary skilled labor to the area in question. Bryan's work mentions an empirical study which concluded that for a large number of firms, especially those which eventually located outside sizable urban regions, the availability of an adequate supply of skilled labor was of considerable importance.[18] Thus, in the case where skilled labor is reluctant to move or where the firm requires a varying amount of

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[18] Ibid., p. 51.

skilled labor, it may be beneficial for the firm to locate near the supply of the type of labor that is required.

While there may be benefits by locating at the source of the skilled labor, it must be recognized that the opportunity cost of such a location may be the foregoing of the location of minimum transport costs or of the point of sales maximization. To quantify the influence of this factor is quite difficult since the inclusion in the previous section of the demand side makes any geometrical or algebraic determination of the point of optimal location impossible. But it is almost necessary for the ultimate decision maker of the firm involved to have this sort of information available in order to make a reasonably good guess at just where the optimum location is. In any event, it is useful to remember that any particular optimum location is optimum for that point in time. Over a period of time, as portions of the population migrate and so on, the point which was once optimum may no longer be so advantageous.

Local levels of taxation and the supply of public services are two more of these additional factors which the firm must consider. Both of these factors are fairly straightforward in that direct costs to the firm can be considered and do not pose the same problems as does the nebulous concept of the availability of skilled labor.

Another factor that should be mentioned is that of local authority cooperation. The proliferation of provincial and municipal "Industrial Development Offices" seems to be more than an implicit recognition that this factor is of some importance in the locational considerations of many firms.

A final, perhaps erratic, factor of industrial location is that of personal considerations. For instance, it is likely that the reason that the United States automobile industry is located in Detroit is that that location was the hometown of Henry Ford. Certainly, it was not because of any market or raw material orientation. It is probable that the location of several other manufacturing industries could be explained in the same manner. As a rule of thumb, one could explain away the more irrational industrial locations as stemming from personal factors provided that one first eliminated governmental subsidies to the producer as an explanation for locating in that area.

Energy Factors

Generally, when the factors of industrial location are being analyzed, energy resources are implicitly treated as just another natural resource and the extent to which energy resources influence the location of industries is calculated in the same manner as is any other natural resource. This is usually restricted to an analysis of transportation costs by the methods outlined previously in this chapter. Isard, for instance, would employ the isodapane technique using cheap power rather than cheap labor as the force that could cause location to deviate from the point of minimum transportation costs.[19] This is necessary for energy resources

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[19]Isard, op. cit., p. 132.

such as electric power which do not possess the properties of weight. Sources such as coal, however, can be analyzed in terms of transport cost in the same manner as any weight losing raw material.

In many writings dealing with location theory the problem of the influence of energy, particularly electricity, is overlooked except for a casual observation that for some electro-process industries the availability of cheap power is likely to be of some significance in determining the location of those industries.[20]

The grave shortage of literature dealing with the role of energy as a determinant of industrial location would lead one to expect there is no overwhelming abundance of data with respect to the Canadian situation. This is indeed the case.

One article that does adequately cover the influence of low cost electricity on industrial location is by Schramm.[21] He claims that for most manufacturing activities, regional differences in the cost of electricity will have little effect on locational decisions, the costs of labor and transportation being the main determinants.[22]

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[20]See, for example, Isard, Location and Space Economy, p. 187, and Edgar M. Hoover, The Location of Economic Activity, (Toronto: McGraw-Hill, 1948), p. 180.

[21]Gunter Schramm, "The Effects of Low-Cost Hydro Power on Industrial Location", Canadian Journal of Economics II, no. 2 (May, 1969), pp. 210-229.

[22]Ibid., p. 211.

He also emphasizes that it is not the absolute cost but the relationship of the costs of energy to the costs of other inputs that is important.[23] For several power intensive industries, Schramm calculated what percentage of the value of total output is comprised of electric energy costs when these costs are varied from two to eight mills per kilowatt hour. Aluminum smelting was the extreme example of an industry for which the total input cost of electricity was high, almost 25 per cent of the delivered price of the metal.[24] For this industry, location near a cheap source of power was almost essential. For the other power intensive industries studied the costs of energy comprised a smaller proportion of the total value and the influence of low cost electricity on industrial location was tempered by the consideration that had to be given to transportation costs. Schramm concluded that "...in many cases, they (power intensive industries) will accept moderate to high power rates in order to escape the penalty of prohibitive freight charges".[25]

He later mentions that, although there exist a number of potential cheap hydro sites, these sites are removed from industrial and population centers, a fact which reduces the attractiveness of their locations.[26]

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[23] Ibid., p. 213.

[24] Ibid., p. 219.

[25] Ibid., p. 219.

[26] Ibid., p. 225.

Dales, in an article, attempts to explain the pattern of industrial development in Central Canada in terms of the availability of different energy resources in Ontario and Quebec.[27] Ontario possesses cost advantages with respect to fuel, Quebec with respect to water power. Thus, other things being equal, one would expect industries requiring large quantities of fuel (principally for heat in the production process) to locate in Ontario and those requiring large quantities of electricity to locate in Quebec. Dales seems to arrive at this conclusion. He mentions that from 1932 to 1946 manufacturing industry in Ontario used about two pounds of bituminous coal to one kilowatt hour of electric power while in Quebec, even after removing the heavily electric intensive nonferrous metals group, the ratio was about 1.4 to one.[28]

It should be noted that the largest problem that both Dales and Schramm faced, one that made it extremely difficult to reach any firm conclusions with respect to the cost of energy as a determinant of industrial location was the lack of useful data that could be used to test any theory. It was impossible to obtain price data for electricity to measure the price differentials between provinces. Nor were price data available for fuel sources such as coal or fuel oil, thus making it impossible to measure interregional price

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[27] John H. Dales, "Fuel, Power and Industrial Development in Central Canada", American Economic Review, 43, part 2 (1953), pp. 181-198.

[28] Ibid., p. 187.

differentials or the degree of substitutability of one fuel for another. This problem of nonavailability of data will also be prominent in the following portions of this thesis.

Summary and Conclusions

When considering the theory of the location of industries, it is vitally important to keep in mind that locational decisions are the result of the several factors considered in the previous sections. It would seem that transportation, labor and agglomeration considerations are the most important as witnessed by the fact that most industry tends to locate near large centers which are already industrialized.

Market factors emphasizing the demand rather than the supply side of industrial activity are also very important. Not to be ignored are varying tax rates in different areas, local authority cooperation and personal factors. With regard to energy resources, it seems that varying costs are of major significance in the locational decisions of only a few industries. For these industries, cheap sources of energy near large centers would be ideal from the point of view of location of these industries.

Based on the theories outlined in this chapter, the remainder of this thesis will attempt to determine if the existence of cheap energy resources, as one of several factors influencing industrial location, causes certain energy intensive industries to locate where they do.

CHAPTER III

THE ENERGY INTENSIVE INDUSTRIES

The objective of this particular chapter will be to determine just which are the energy intensive industries in terms of the costs of all inputs. To achieve this goal the chapter will be divided into four major sections. The first section will define the energy resources which are under study. The second will be a description of the methodology and of the data sources employed in the study. Third will be a listing of the industries which are energy intensive. The fourth section will identify the major inputs and industrial classification of each energy intensive industry. From this will come an attempt to determine which locational factor (transportation, labor, cheap energy, etc.) has the largest single influence on the location of each particular industry. In later chapters those industries for which cheap energy is a major determinant will be more thoroughly analyzed.

The Energy Resources

The energy resources will perform a number of functions in an economy. They may provide feedstock, motive power or thermal-chemical power to the production process of several industries.

Fossil Fuels

In the case of fossil fuels (i.e. petroleum, natural gas, coal and coke) energy is produced by combustion in the form of heat. If the requirement of an energy resource is merely to provide heat, then for that purpose the fossil fuels may be regarded as substitutes for one another.

Coal. One of the most common of the energy resources is coal. It is used both as a fuel (i.e. as a source of heat) and as a raw material into the production process. An example of this is the iron and steel industry, which uses coal in both capacities.

In 1969 the industrial consumption of coal in Canada was 16,881,129 short tons, while 5,521,516 tons of coke were consumed.[1] Ontario was by far the largest consumer with 10,088,980 tons of coal consumed of which 9,090,665 tons were imported.[2] Quebec, the second largest consumer among the provinces, used only 1,221,150 tons, of which 372,338 were imported.[3] With respect to industrial consumption of coke Ontario was again the largest consumer, using 3,956,052 tons, most of it domestically produced, compared to 1,952,637 tons in Quebec, the second largest province in terms of consumption.[4] Given these figures it is not surprising to find that there is an association between the consumption of coal in Ontario

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[1]Canada, Dominion Bureau of Statistics, The Coal Mining Industry, 1969, (Ottawa: Queen's Printer), p. 10.

[2]Ibid., p. 49.

[3]Ibid., p. 43.

[4]Ibid., p. 43 and p. 49.

and its large amount of manufacturing activity which requires thermal energy.[5]

Natural Gas. Natural gas is of use, both as a fuel and as a feedstock, in the production process of several industries. It is composed of hydrocarbons of the paraffin series. It is found alone or with petroleum. Methane is by far its largest component with ethane, propane and butane also present but in much smaller proportions. It is of some importance as a feedstock in the manufacture of organic chemicals and as a fuel to generate electric power thermally. With the probable increase in demand for fuels which are not major pollutants the importance of natural gas to the economy will likely rise sharply. This trend is already evident. In 1960 the industrial consumption of natural gas was 162.4 billion cubic feet. Consumption has increased every year to the point where 489.5 billion cubic feet were consumed for industrial use in 1970.[6]

Petroleum. A broad energy category is petroleum. One of its subdivisions is loosely classified as crude mineral oils. It applies to oil in its crude form rather than as a processed energy resource. For only one industry, petroleum and coal products, does it comprise a significant proportion of total inputs.

A second petroleum resource is gasoline, a refined form of the classification of crude mineral oils. The most obvious use of

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[5]For a detailed explanation of this type of association see J.H. Dales, "Fuel, Power and Industrial Development in Central Canada", American Economic Review, XLIII, part 2 (1953), pp. 181-198.

[6]Canadian Gas Association, Statistical Summary--1970 (Don Mills: 1971), p. 2.

gasoline is as a fuel for the internal combustion engine. In 1969 sales of motor gasoline in Canada totalled 158,584,671 barrels while sales of aviation gasoline totalled 1,626,896 barrels.[7]

Another classification of petroleum resources is fuel oil. It is used primarily for residential and industrial heating. Fuel oil is a significant input into several mining industries. In 1969 total Canadian sales of all types of fuel oils (light, heavy and diesel) totalled 244,083,021 barrels.[8] Grouped together in the petroleum family of natural resources is the miscellaneous category of other petroleum products. These include, among others, such diverse products as asphalts, paraffin wax and lubricants.

Electricity

In addition to the fossil fuels, there is the energy resource of electricity. Although its use is all pervasive it does not comprise a significant proportion of the total costs of inputs of more than a few major industries. Besides the aluminum smelting industry the industries which require vast amounts of electric power are the pulp and paper industry and various mineral industries.[9] One aspect concerning the production of electric power is that if

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[7]Canada, Dominion Bureau of Statistics, Refined Petroleum Products, 1969, p. 4.

[8]Ibid., pp. 17-18.

[9]The mineral industry consumes just over one fifth of the electric energy produced in Canada; the pulp and paper industry just under one fifth. See: Canada, Department of Northern Affairs and Natural Resources, Electric Power in Canada, 1964, (Ottawa: Queen's Printer, 1964), p. 16.

electricity is not produced by hydro power, then coal, fuel oil or natural gas is required to produce electricity thermally. It is interesting to note that in 1969 hydro power accounted for only 68 per cent of the total Canadian generating capacity of 39,838 megawatts, or 27,114 megawatts, with thermal power accounting for the rest, whereas in 1950 hydro power accounted for over 90 per cent of total electric generating capacity.[10]

In addition to ordinary thermal plants Canada's first nuclear powered plant was scheduled for completion at Pickering, Ontario in 1971.[11]

In 1969 industrial establishments accounted for 13.2 per cent of installed generating capacity in Canada and for 17.6 per cent of the electrical energy produced.[12] These figures are an indication of the significance of electricity as an input of certain industries.

Thus we have the energy resources: coal, natural gas, electricity, crude mineral oils and the refined versions of this fourth resource, namely gasoline, fuel oil and other petroleum products.

The major working hypothesis of this study will be that to the extent that one of these energy resources must be used exclusively in the production process of an industry, a region in which the particular energy resource that is required is relatively cheaper

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[10] Ibid., 1969, p. 3.

[11] Ibid., p. 14.

[12] Ibid., p. 14.

than in other regions would be expected, ceteris paribus, to have a locational advantage over other regions. If, on the other hand, these energy resources are substitutes for one another, for instance fuel oil and natural gas for many heating purposes, then a region with an abundant supply of one of these resources may not possess a significant locational advantage if the firms in that industry can purchase the Btu. equivalent from a substitute source in another region at a similar price. Essentially, the question of whether or not an energy resource possesses a locational attraction for an industry depends upon the portion of total input costs comprised of the costs of that energy input and also upon the substitutability of one energy resource for another. Energy resources used as feedstocks, however, are less likely to possess that property of substitutability since it is the specific properties of that energy resource that are required in the production process of the industry in question.

Sources and Methodology Used in the Study

Input-Output Tables

For the empirical sections of this study publications of the Dominion Bureau of Statistics have been heavily relied on. The first of these was the Input-Output tables of 1961.[13] This was an extensive undertaking attempting to measure virtually all of the flows of goods and services in the Canadian economy. In its largest

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[13]Canada, Dominion Bureau of Statistics, The Input-Output Structure of the Canadian Economy, 1961, (Ottawa: Queen's Printer, 1969).

aggregation it has 110 industries and 197 commodities. For the purposes of this study only those 98 industries which can be considered as being primary or manufacturing (either primary or secondary manufacturing) are observed. The total energy inputs into each of the industries were calculated. This was done for each energy resource. The amount of energy used was calculated as a percentage of total input costs in order to determine just which are the energy intensive industries. Obviously, the choice of what is an energy intensive industry becomes very arbitrary.

The use of input-output tables has both merits and demerits. The first of its merits is that it is possible to determine the importance of a particular commodity to any industry. In this case it is possible to determine the importance of energy to particular industries. Another useful characteristic of input-output tables is that the effects of a change in demand for a final product can be traced through the tables to measure the effects on the demand for intermediate products. If, for example, it is expected that the demand for steel will increase, then one could project, from input-output tables, the additional amounts of energy inputs (and of course, of all other inputs) which would be required by the steel industry. Thus, it is seen that input-output tables are useful in that they can show the importance of various inputs into each industry. In addition they can predict changes in demand for intermediate products due to a change in demand for final products. Given these characteristics, it seems clear that input-output tables can be a useful tool of economic analysis.

There is one major drawback to the use of input-output tables, though. The data used are necessarily for a fixed point in time. This means that the tables explain the situation as it was when the data were collected (in this case 1961). Therefore, one must operate on the implicit assumption that for every industry there are fixed coefficients of production. That is, that the inputs into the production process are always used in the same proportions and that no technical change takes place. This characteristic of input-output tables makes dynamic analysis difficult and forces one to resort to a static type of analysis.

In a sense it is fortunate that 1961 was the year for which the data for the input-output tables were calculated. Detailed Census data are available for that year and will be used in latter parts of this study. Thus, for much of the analysis, some consistency will be observed with respect to the point in time that is considered.

Census of Manufactures

Besides the 1961 Input-Output Tables substantial use was made of the individual industry reports of the Census of Manufactures publications of the Dominion Bureau of Statistics. The most useful characteristic of this data source was the fact that some breakdown of data by provinces is provided. This could be useful in determining such things as interregional price differentials and location quotients of energy intensive industries.

Other Sources

In addition to Dominion Bureau of Statistics publications, material from such sources as the National Energy Board, the Hydro-Electric Power Commission of Ontario and the Quebec Hydro-Electric Commission was employed in an attempt to obtain useful statistics. While some useful information was gathered it was not sufficient to test all of the hypotheses that could be developed. In short, the total data that could be used was less than adequate to meet the objectives of this study.

The Energy Intensive Industries

In order to identify the energy intensive industries calculations were made from the 1961 Input-Output tables regarding the amount of energy inputs as a percentage of total input costs for 97 industries in the tables. Total inputs were calculated as the sum of material inputs plus value added. Therefore some types of inputs such as transportation were not included in the measurements.

The choice of what comprised an energy intensive industry was arbitrarily chosen as being any industry for which the costs of energy inputs exceeded five per cent of total input costs. Using this cutoff figure of five per cent, 20 industries of the original 97 remained which could be considered as being energy intensive.

The following table will list the 20 energy intensive industries and the percentage of total input costs that are comprised

of energy inputs. The latter will be denoted by the symbol EI/TI.

TABLE 1

ENERGY INPUTS AND THE ENERGY INTENSIVE INDUSTRIES

Industry	EI/TI
Petroleum and Coal Products	64.802
Coal Mines	24.407
Other Metal Mines	22.029
Other Nonmetal Mines	21.558
Asbestos Mines	20.769
Agriculture	17.822
Fishing and Hunting	17.204
Base Metal Mines	15.769
Petroleum, Gas and Services Incidental to Mining	14.585
Iron Mines	13.053
Uranium Mines	12.760
Industrial and Other Chemicals	11.098
Cement and Lime Products	10.644
Forestry	10.260
Iron and Steel Mills	8.883
Asphalt Roofing Manufacturers	8.851
Other Nonmetal Mineral Producing Industries	6.285
Pulp and Paper Mills	6.090
Clay, Stone and Refractory Products	5.475
Manufacturers of Plastic Resins	5.109

Source: calculated from Dominion Bureau of Statistics, The Input-Output Structure of the Canadian Economy, 1961, Volume 2, Table 13.

Table 1 indicates that even among these 20 industries the importance of energy varies. The most energy intensive industries in terms of their total inputs are the primary industries. Although

cheap energy inputs are important to these industries it is generally an immobile natural resource that provides their chief locational attraction. In such cases cheap energy may influence a firm's choice between two or more possible locations. In the case of both primary and secondary manufacturing industries energy is but one of several factors which influence the location of industry. Again it can be a deciding factor in the locational decisions of firms.

In the following pages tables will show, for each of the energy intensive industries, the percentage of total input costs that are comprised of various classifications of inputs. In addition there will be some discussion of the locational characteristics of each energy intensive industry. In the tables the following notation will be used:

EI = energy inputs	MEI = main energy input used
TI = total inputs	PLE = primary less energy inputs
LI = labor inputs	T = transportation inputs
KI = capital inputs	TVOP = total value of product

Abbreviations used for the different energy inputs will be obvious.

Locational Characteristics of the Energy Intensive Industries

Specific Factors

Capital Inputs will be shown to comprise a high proportion of total input costs for all of the industries under study. In the case of the primary industries no entries were made for labor and capital inputs since the relevant data were not available. For the manufacturing industries that were considered as being energy intensive

capital inputs were very high. For only one industry, petroleum and coal products, did these costs fall below 20 per cent of total costs. Capital can be considered as being quite mobile, however, and can be regarded as a cost that would be incurred at any location. Thus, to a large extent, the cost of capital can be disregarded as being a decisive factor when choosing a particular location for a firm in one of the energy intensive industries.

Labor Inputs. Labor is another input whose costs are a significant proportion of total input costs. The cost of labor, as has been mentioned previously, can vary among regions and therefore can influence a firm's choice of location. For only one of the industries listed in Table 1, petroleum and coal products, does the cost of labor fall below 15 per cent. Yet it is difficult to categorize any of those industries as having labor costs as their principal determinant of location.

Primary Inputs. The category of primary inputs minus energy inputs can be considered as a measurement of the natural resource inputs of any particular industry. For the primary industries it is an immobile natural resource that is the prime determinant of location. For the manufacturing industries the cost of natural resource inputs is a less significant determinant of location, its importance being reduced by the costs of such other inputs as transportation and energy.

Transportation Inputs. At first glance the size of transportation costs relative to total costs of an industry would lead

one to conclude that transportation costs should be given over-riding consideration in the locational decisions of firms in the energy intensive industries. For 11 of the industries in Table 1 transportation costs exceed five per cent of total costs. Further examination would show, however, that with one exception, petroleum and coal products, these industries are primary industries. Their locations are generally determined by immobile natural resources and firms in the industries have little choice but to absorb the transportation costs or to pass them on to consumers. For the nine remaining industries transportation costs are below five per cent. This is because firms have chosen to minimize transportation costs or because the costs of other inputs are very high. To repeat, the fact that transportation costs are high for many of the energy intensive industries does not necessarily imply that several firms in those industries are not optimally located; instead it indicates a fundamental characteristic of those industries.

Energy Inputs. Finally there are are the energy inputs. As stated, for each of the industries in Table 1 the cost of energy exceeded five per cent of total input costs. For some of the manufacturing industries the existence of cheap energy could be the single most important determinant of location. For primary industries the site of a particular natural resource will be the major determinant but the existence of a cheap energy resource could influence the choice between two or more locations.

Classification of the Energy Intensive Industries

Primary Industries. Previously in this chapter the energy intensive industries have been referred to as being either primary or manufacturing industries. The primary industries are of four main types: agriculture, fishing, forestry and mining. The term primary industry excludes those activities involved in the processing or conversion of the primary products.[10] The various primary industries exhibit several common characteristics. Their activities usually take place far from large urban centers. This aspect reflects itself in high transportation costs and in difficulties in attracting and retaining skilled labor. In addition the primary industries tend to be the largest exporting industries in terms of total Canadian exports.[11]

Manufacturing Industries. Unlike the primary industries, the manufacturing industries are involved in the processing and conversion of products. A dichotomy has developed in the classification of manufacturing industries. They can be classified as being either primary or secondary manufacturing. Whether a manufacturing industry is considered as being primary or secondary depends on the composition

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[10]This definition is taken from: Economic Council of Canada, First Annual Report, Economic Goals to 1970, (Ottawa: Queen's Printer, 1964), p. 134.

[11]Ibid., p. 135.

of its inputs. Primary manufacturing industries are those for which more than one half of the material inputs come from the primary industries. All other manufacturing activity can be regarded as being secondary manufacturing.[12] Like the primary industries, the primary manufacturing sector tends to be export oriented and to some degree could be considered as an extension of the primary sector.[13] Of the industries listed in Table 1 four are primary manufacturing industries: pulp and paper mills, cement and lime products, clay stone and refractory products and petroleum and coal products. Five others are secondary manufacturing: iron and steel mills, asphalt roofing, other nonmetal mineral producing industries, plastic resins and industrial and other chemicals. All other industries listed in the table are primary industries.

Primary Industries

Agriculture. It is not necessary to carry out an elaborate analysis of the locational characteristics of the agriculture industry. It is obviously the existence of suitable farm land which determines the location of those engaged in this industry. The following table will show some of the major inputs into this industry.

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[12]Dominion Bureau of Statistics, Primary and Secondary Manufacturing in Canada, (unpublished), p. 3.

[13]Ibid., p. 1.

TABLE 2

MAJOR INPUTS - AGRICULTURE

%EI/TI	%PLE/TI	%T/TVOP	MEI
17.822	38.573	7.383	G
%MEI/TI	%MEI/EI	MEI/PLE	MEI/T
11.798	66.229	0.305	1.480

Source: calculated from Dominion Bureau of Statistics, The Input-Output Structure of the Canadian Economy, 1961, Volume 2, Table 13.

Table 2 shows that while gasoline, the main energy input into the agriculture industry, is a necessary input its influence is not decisive with respect to location. This is borne out by the low ratio (0.305 to 1) of the main energy resource to natural resource inputs.

Forestry. The forestry industry is similar to agriculture with respect to its locational characteristics. Gasoline is an important energy input as is transportation. It is, however, natural resource inputs which determine the location of this industry.

TABLE 3

MAJOR INPUTS - FORESTRY

%EI/TI	%PLE/TI	%T/TVOP	MEI
17.204	42.722	12.490	G
%MEI/TI	%MEI/EI	MEI/PLE	MEI/T
5.058	49.777	0.118	0.354

Source: calculated from Dominion Bureau of Statistics, The Input-Output Structure of the Canadian Economy, 1961, Volume 2, Table 13.

The low ratios, MEI/PLE and MEI/T suggest that gasoline, the main energy input, is not too significant a factor in the location of the forestry industry.

Fishing and Hunting. The situation for this industry is similar to agriculture and forestry. Gasoline is important in terms of total costs as is transportation. It is, however, the location of fish and game that determines the location of this industry.

TABLE 4

MAJOR INPUTS - FISHING AND HUNTING

%EI/TI	%PLE/TI	T/TVOP	MEI
17.204	17.204	13.622	G
%MEI/TI	%MEI/EI	MEI/PLE	MEI/T
17.204	100.000	1.000	1.096

Source: calculated from Dominion Bureau of Statistics, The Input-Output Structure of the Canadian Economy, 1961, Volume 2, Table 13.

Actually, Table 4 says little that is definite about the locational characteristics of the fishing and hunting industry. One must rely on common sense to reach the conclusion that it is the location of the fish and game that is the locational determinant of this industry.

Mining. The various mining industries are also energy intensive. For them electricity is the chief energy input. The mining industries can be divided into two broad categories; those for which there is only one mine site in the country and those for which several alternative sites exist. Examples of the former case would be uranium mines and asbestos mines. Coal mining would be the best example of a mining industry which has a number of sites throughout the country. In the latter case factors such as transportation costs and cheap energy would have some influence on a

firm's choice between two or more sites.

TABLE 5

MAJOR INPUTS - MINING

	%EI/TI	%PLE/TI	%T/TVOP	MEI
Iron Mines	13.053	18.526	10.377	E
Base Metal Mines	15.679	18.486	5.362	E
Uranium Mines	12.760	8.605	7.418	E
Other Metal Mines	22.029	16.812	3.361	E
Coal Mines	24.407	7.407	5.594	E
Asbestos Mines	20.769	13.462	5.455	E
Other Nonmetal Mines	21.558	7.792	10.879	E

	%MEI/TI	%MEI/EI	MEI/PLE	MEI/T
Iron Mines	7.153	54.838	0.386	0.618
Base Metal Mines	12.245	78.151	0.650	2.162
Uranium Mines	7.120	55.814	0.827	0.888
Other Metal Mines	19.980	90.789	1.189	5.750
Coal Mines	20.428	83.783	0.861	3.875
Asbestos Mines	12.295	59.259	0.914	2.133
Other Nonmetal Mines	7.523	34.939	0.966	0.617

Source: calculated from Dominion Bureau of Statistics, The Input-Output Structure of the Canadian Economy, 1961, Volume 2, Table 13.

The category of other metal mines refers primarily to nickel mines. There are very few concentrations of nickel ore in Canada and thus cheap electricity would not provide a major locational pull. Regarding base metal mines (mainly lead and zinc) there are considerably more possible mine sites than for other metal mines and thus the availability of cheap electricity could influence the location of mine sites.

Other nonmetal mines includes limestone and similar products. There are a great many deposits throughout the country. Cheap

electricity could be almost as important as minimizing transportation costs as a determinant of location.

In the case of asbestos mines and uranium mines the mining companies involved have little or no choice between alternative sites. This situation also applies to iron mines. Although substantial iron ore deposits exist in the Northwest Territories transportation costs would be too great to establish mine sites there. This is not always the case however. There are many mining industries located in Northern Canada. This location subjects them to high transportation costs as well as high energy costs. These costs can be absorbed by the mining companies only if they are exploiting very large bodies of high grade ores.

As far as coal mines are concerned there are many likely sites across the country. Electricity is a major input, comprising 20.428 per cent of total costs. Transportation costs are also high. Because there exist many possible sites to establish coal mining operations, these two factors do have some significance in the locational decisions of firms. Labor costs would be almost uniform across the country since workers are unionized. Capital is the most mobile of the factors and hence has little influence on location. Thus firms in the coal mining industry will choose to locate at a deposit where they are able to minimize transportation costs or costs of electric power or some combination of the two.

Petroleum, Gas and Services Incidental to Mining. The products of this industry include natural gas, sulphur and various other material inputs and services required by the mining industry.

TABLE 6

MAJOR INPUTS - PETROLEUM, GAS AND SERVICES INCIDENTAL TO MINING

%EI/TI	%PLE/TI	%T/TVOP	MEI
14.585	35.546	8.765	E
%MEI/TI	%MEI/EI	MEI/PLE	MEI/T
9.520	65.209	0.267	0.990

Source: calculated from Dominion Bureau of Statistics, The Input-Output Structure of the Canadian Economy, 1961, Volume 2, Table 13.

The description of this industry is quite vague but some hypothesis of the locational determinants of this industry can be made. The costs of both transportation and of electricity comprise substantial proportions of total input costs. The same can be said of primary inputs. One would conclude, however, that since the industry services mining industries, location takes place near mine sites.

Primary Manufacturing Industries

Pulp and Paper Mills. The pulp and paper industry is very important to the Canadian economy. In 1968 its products accounted for $1,784,608,000 or 13.49 per cent of the total dollar value of

Canadian exports for that year.[14] In addition it employed 73,498 persons in 1968.[15] Thus it could be useful for policy makers to know something of the necessary prerequisites to influence a pulp and paper company to locate in a certain area.

TABLE 7

MAJOR INPUTS - PULP AND PAPER

%EI/TI	%PLE/TI	%LI/TI	%KI/TI	%T/TVOP
6.090	30.659	21.023	31.816	3.411
MEI	**%MEI/TI**	**%MEI/EI**	**MEI/PLE**	**MEI/T**
E	3.787	62.203	0.114	1.072

Source: calculated from Dominion Bureau of Statistics, The Input-Output Structure of the Canadian Economy, 1961, Volume 2, Table 13.

Table 7 indicates that capital inputs account for the largest percentage of input costs. Since capital is the most mobile of all of the factors listed it cannot be regarded as being a major locational determinant of firms in this industry. Labor is not a major determinant of the location of firms in the pulp and paper industry since labor is unionized and wages are effectively equalized across the nation.

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[14] Dominion Bureau of Statistics, Trade of Canada - Summary of Exports, December 1968, pp. 5-6.

[15] Dominion Bureau of Statistics, Pulp and Paper Mills, 1968, p. 3.

It is obvious that natural resource inputs, in this case forestry inputs, are of extreme importance to this industry. Since the raw materials (i.e. pulpwood logs) lose weight when being made into pulp it is sensible to locate near a forest site rather than to transport them over a long distance to the market. Furthermore, as pulpwood grows scarce its costs increase by more than the cost of transport.[16] This is an additional pull towards the forest site.

At first glance it would seem that electricity, the main energy input into the pulp and paper industry, is not too important a factor in the locational decisions of firms in that industry. Further examination would show, however, that electricity is very important to the industry. The pulp and paper industry consumes approximately one fifth of the electric energy generated in Canada.[17] In addition most pulp and paper companies own their own electricity generating plants.[18] A further indication of the importance of electricity to the pulp and paper industry is the ratio of the costs of electricity to the costs of transportation (1.072 to 1) since it is apparent that firms in the industry are cognizant of transportation costs.

Undoubtedly, firms in the pulp and paper industry must locate

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[16]Helen Hunter, "Innovation, Competition and Locational Changed in the Pulp and Paper Industry: 1880-1950", Land Economics, XXXI, No. 4, (November 1955), p. 315.

[17]Department of Northern Affairs and Natural Resources, op. cit. p. 16.

[18]Ibid., pp. 105-114.

at suitable forest sites. It is likely, though, that they chose the particular sites that they did because of the feasibility of installing a necessary generating plant. In short, low cost electricity is a secondary influence on the location of pulp and paper mills but it is certainly significant enough to influence the choice between two or more sites.

Cement and Lime Products. The principal locational factors for this industry are not as easily defined as are those for the pulp and paper industry. Due to the bulky nature of the product and due to the fact that the raw materials lose weight during the production process it could be expected that location near the market place would characterize the cement and lime products industry. In fact the industry is characterized by a number of small local markets.

TABLE 8

MAJOR INPUTS - CEMENT AND LIME PRODUCTS

%EI/TI	%PLE/TI	%LI/TI	%KI/TI	%T/TVOP
10.644	3.575	16.466	52.902	3.978
MEI	%MEI/TI	%MEI/EI	MEI/PLE	MEI/T
C	4.769	45.038	1.340	1.156

Source: calculated from Dominion Bureau of Statistics, The Input-Output Structure of the Canadian Economy, 1961, Volume 2, Table 13.

Capital inputs are the largest single type of input into the cement and lime products industry. Since capital is quite mobile

its influence on the location of firms in the industry is minor. The costs of labor are quite low (16.466 per cent of total costs). It does not matter whether this reflects the capital intensive nature of the industry or a condition of low wages in the industry. It is unlikely that cheap labor is a significant determinant of location for the cement and lime products industry.

Transportation costs seem low (3.978 per cent of total value of product). This is probably because of the fact that the industry is characterized by several local markets.

Coal, the main energy input comprises only 45.038 per cent of the total costs of energy inputs. There are two reasons for this. One is that electricity is also a fairly significant input into this industry. Another is that natural gas may be used as a substitute for coal for heating purposes.

The locational characteristics of the cement and lime products industry can be summed up briefly. Location near limestone deposits, gravel pits and so on is desirable. Transportation costs are high so a pattern of several regional markets exists. Coal, the main energy input, is less important than one would expect, its significance being reduced by other energy resources, namely electricity and natural gas. In short, the industry is transport orientated with energy prices playing only a minor role in the locational decisions of firms in the industry.

Clay, Stone and Refractory Products. Before analyzing the locational determinants of firms engaged in the manufacture of clay, stone and refractory products it is useful to know just what these

products are. Some imported clays are used in the manufacture of pottery, chinaware and so on. Domestic clays are used in the manufacture of such products as clay brick, floor and wall tile and sewer pipe. Refractory products include such items as fire brick, crucibles, cements, mortars and so on. Stone producers include establishments engaged in cutting, shaping and finishing stone for other purposes. Monuments and tombstones are examples of products of this industry.

TABLE 9

MAJOR INPUTS - CLAY, STONE AND REFRACTORY PRODUCTS

%EI/TI	%PLE/TI	%LI/TI	%KI/TI	%T/TVOP
5.475	16.663	32.439	30.426	4.108
MEI	**%MEI/TI**	**%MEI/EI**	**MEI/PLE**	**MEI/T**
E & F	1.664 each	30.434 each	0.100	0.338

Source: calculated from Dominion Bureau of Statistics, The Input-Output Structure of the Canadian Economy, 1961, Volume 2, Table 13.

For the clay, stone and refractory products industry immobile resources such as clays, silica sand, quartz and stone provide a major locational pull. Labor is also a significant input in terms of its costs.

The importance of energy would appear to be slight. Electricity and fuel oil comprise the same proportion of total costs of

this industry. The ratio of either of these to natural resource inputs or to transportation costs is small. It appears that transportation costs are fairly important to this industry. It is likely that it is comprised of several local markets, reflecting a transportation orientation of the industry.

Petroleum and Coal Products. The products of this industry include benzene, xylene, butane, other liquified petroleum gases, naptha, petroleum jelly, asphalt, coal oils, briquettes and several other products. For the most part these are products of petroleum refineries.

TABLE 10

MAJOR INPUTS - PETROLEUM AND COAL PRODUCTS

%EI/TI	%PLE/TI	%LI/TI	%KI/TI	%T/TVOP
64.802	0.918	7.461	16.974	8.686
MEI	**%MEI/TI**	**%MEI/EI**	**MEI/PLE**	**MEI/T**
CMO	63.164	97.471	68.809	6.640

Source: calculated from Dominion Bureau of Statistics, The Input-Output Structure of the Canadian Economy, 1961, Volume 2, Table 13.

It is obvious from Table 10 that the major input of the petroleum and coal products industry is that energy resource referred to as crude mineral oils. Transportation costs are also important. Due to the technology of the petroleum industry it is easier to

transport the crude oil by pipeline than it is to ship the refined final products. Thus it would seem that the petroleum products industry is transport oriented in that the industry attempts to locate near large markets in order to minimize the transportation costs of final products.

With respect to coal products, it is probably cheaper to ship the coal as a raw material to the market place than to process it near the mine site and then to transport the final product to the market. This is obviously true for such products as asphalt paving mixtures.

It would seem reasonable to conclude that the petroleum and coal products industry is transport oriented. Manufacturers of petroleum products and of coal products will locate near the market in order to minimize transportation costs of final products. This conclusion must be qualified, however, by a reference to a recent innovation of the petroleum industry. This is the concept of product pipelines which can have the effect of large scale refinery consolidation. An example of this is in Alberta. A large, new refinery was built in Edmonton and another refinery was shut down in Calgary. Refined products are transported to Calgary by pipeline from Edmonton. This is a case where economies of scale in refinery operations are significant enough to offset the increased costs incurred by transporting the refined products from Edmonton to Calgary. Whether this is an exception to the transportation orientation of the industry or will become the rule remains to be seen.

Secondary Manufacturing Industries.

Iron and Steel Mills. The iron and steel industry is generally considered to be transportation oriented. Costs of transporting raw materials to the plant and of shipping final products to the market will provide the major cost differentials among regions. Isard and Capron contend that "...the problem of supplying a sizable market area is essentially the selection of a particular site which will minimize the transport cost incurred in assembling raw materials and shipping the final product".[17]

TABLE 11

MAJOR INPUTS - IRON AND STEEL MILLS

%EI/TI	%PLE/TI	%LI/TI	%KI/TI	%T/TVOP
8.883	25.859	26.648	27.873	3.479
MEI	%MEI/TI	%MEI/EI	MEI/PLE	MEI/T
C	5.818	65.570	0.225	1.605

Source: calculated from Dominion Bureau of Statistics, The Input-Output Structure of the Canadian Economy, 1961, Volume 2, Table 13.

It might appear from Table 11 that transportation costs are really not too important to the iron and steel industry. Most of

[17]Walter Isard and William Capron, "The Future Locational Pattern of Iron and Steel Production in the United States", Journal of Political Economy LVII, no. 2 (April, 1949), p. 120.

the input costs are accounted for by three input categories: natural resources, labor and capital. Capital, however, can again be considered as being quite mobile. Labor is unionized, leading one to expect that no significant wage differential would exist among regions.

Natural resource inputs could be of some influence in the locational decisions of firms planning to establish iron and steel mills. Iron ore, for example, could vary from site to site, with respect to the costs of mining the ore and with respect to the quality of the ore.

The location of steel mills in Canada does not follow any apparent pattern, other than to minimize total input costs. The large mill in Nova Scotia, for example, is located near vast deposits of coal. There is a steel mill in Kimberly where there are deposits of high quality iron ore which can be exploited cheaply. The low cost of this iron ore more than offsets the higher costs of transporting the final product to the market. In Edmonton readily available scrap steel which can be used as an input makes the operation of a steel mill feasible.

The location of the huge steel mill in Hamilton can be analyzed in terms of the theories presented in Chapter Two. The firm attempts to minimize transportation costs. The Hamilton location allows the firm to minimize the costs of transporting iron ore from northern Ontario and coal from Pennsylvania. In addition this location is near the large southern Ontario market.

It should be noted that the iron and steel industry is becoming more and more market oriented. One reason for this is the increasing use of scrap steel as an input. The best sources of scrap steel are the existing large markets. Another reason for a market orientation of the industry is the fact that there is an increasing amount of vertical integration in the industry. Thus shaped finished products (eg. automobile bumpers) are being produced and the cost of transporting these finished products is much higher than that of transporting steel ingots. Given these factors it seems that in the future iron and steel mills will continue to be transportation oriented with the existence of scrap steel and the cost of shipping final products being as important as access to iron ore and coal.

Asphalt Roofing Manufacturers. The principal product of this industry is roofing shingles. One would immediately expect a transportation orientation of this industry. The products are bulky and have a low value. A pattern of local markets would be expected.

TABLE 12

MAJOR INPUTS - ASPHALT ROOFING

%EI/TI	%PLE/TI	%LI/TI	%KI/TI	%T/TVOP
8.851	24.271	21.258	26.767	4.451
MEI	**%MEI/TI**	**%MEI/EI**	**MEI/PLE**	**MEI/T**
OPP	2.743	53.703	0.303	1.579

Source: calculated from Dominion Bureau of Statistics, The Input-Output Structure of the Canadian Economy, 1961, Volume 2, Table 13.

Table 12 suggests that natural resource inputs are very important to this industry. These resources are so varied, however, that no one of these significantly affects the location of the asphalt roofing industry. Transportation costs are important, representing 4.451 per cent of the total value of product. Transportation costs are about two thirds as high as are the costs of the main energy input, other petroleum products. Here the other petroleum products are represented primarily by asphalt. Thus for the asphalt roofing industry the costs of asphalt and of transportation are quite important. Due to the bulky nature and the low value of the product as well as high transportation costs a pattern of local markets exists for the asphalt roofing industry.

Other Nonmetal Mineral Products Industries. This industry category is quite vague. Its products include such things as mineral wool, certain thermal insulation materials, some types of asbestos products and abrasives.

TABLE 13

MAJOR INPUTS - OTHER NONMETAL MINERAL PRODUCTS INDUSTRIES

%EI/TI	%PLE/TI	%LI/TI	%KI/TI	%T/TVOP
6.285	19.711	27.657	26.637	2.867
MEI	**%MEI/TI**	**%MEI/EI**	**MEI/PLE**	**MEI/T**
E	5.141	81.818	0.260	1.741

Source: calculated from Dominion Bureau of Statistics, The Input-Output Structure of the Canadian Economy, 1961, Volume 2, Table 13.

Several factors combine to make it difficult to determine just what are the main locational factors of this industry. One is simply the multiplicity of products manufactured by this industry category. Natural resource inputs account for a large proportion of total input costs. Yet there are so many different kinds of natural resource inputs that they cannot be considered a principal determinant of location for this industry. Capital is relatively mobile so it does not exert much of a locational pull. Labor, if the wage rate varies across the country, could be of some influence on the location of firms in this industry.

Transportation costs are low, suggesting that firms are already minimizing transportation costs or that such costs are unimportant to firms in the industry. The cost of electricity comprises 5.141 per cent of total costs. This is a significant percentage but is probably not enough to provide a decisive pull to any one location.

Although one is unable to make a decisive statement about the locational characteristics of the other mineral products industry it would probably not be incorrect to conclude that this industry is footloose with respect to its location.

Manufacturers of Plastics and Synthetic Resins. This industry includes firms engaged in the manufacture of transparent cellulose film as well as synthetic resins in the form of granules, flakes and liquids.

TABLE 14

MAJOR INPUTS - PLASTICS AND SYNTHETIC RESINS

%EI/TI	%PLE/TI	%LI/TI	%KI/TI	%T/TVOP
5.109	5.478	17.508	27.054	3.293
MEI	**%MEI/TI**	**%MEI/EI**	**MEI/PLE**	**MEI/T**
OPP	2.743	53.703	0.500	0.659

Source: calculated from Dominion Bureau of Statistics, The Input-Output Structure of the Canadian Economy, 1961, Volume 2, Table 13.

Table 14 does not allow one to make definite statements about the locational characteristics of this industry. Transportation costs are not too large a percentage of total costs. The main category of energy inputs, other petroleum products, is not too large either. Nor do primary inputs provide a major locational pull, as this category of input accounts for only a small proportion of total input costs. Capital inputs can again be considered as being quite mobile, and thus are not a major locational determinant of the plastic and synthetic resins industry. Labor inputs are also unlikely to be too significant in determining location.

It can be concluded that none of the above mentioned factors exerts a very strong locational pull on the plastics and synthetic resins industry. Agglomerative factors, on the other hand, could be said to have a profound influence on the location of firms in this industry. In 1961 organic chemicals accounted for $21.0 millions of

a total of $58.2 millions spent on material inputs (i.e. physical goods) by the industry.[18] The organic chemicals industry, in turn, tends to be located near petroleum refineries. Thus, one could justifiably state that agglomeration economies provided by petroleum refineries and organic chemical plants are a powerful locational attraction to the plastic and synthetic resins industry.

Industrial and Other Chemicals. Before any analysis of the locational characteristics of the industrial and other chemicals industry can take place some discussion of the characteristics of this industry would be useful.

First of all one must distinguish between organic and inorganic chemicals. Inorganic chemicals are commodities such as chlorine, sulphuric acid, aluminum sulphate and similar products (i.e. acids, salts and alkalis). It would seem that their production would rely heavily on electrolytic processes. Hence cheap electricity would be important to firms that manufacture these chemicals. Schramm puts much emphasis on the influence of low cost electricity. He concludes that there is a tradeoff between power rates and freight charges.[19]

Organic chemicals are chemicals such as ethylene, acetylene,

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[18]Calculated from Dominion Bureau of Statistics, The Input-Output Structure of the Canadian Economy, 1961, Volume 2, Table 13.

[19]Schramm, op. cit., p. 219.

acetic acid, hydro carbons and their derivatives and similarly produced goods. This type of product would require substantial feedstocks of petroleum and natural gas. Thus, for organic chemicals, proximity to refineries would be an important factor in the locational decisions of firms processing these products.

In addition to organic and inorganic chemicals there is a difference between industrial and non-industrial use. Prime examples of non-industrial chemicals are various types of fertilizers, synthetic rubber and various types of automotive chemicals.

It is unfortunate that the classification of industrial and other chemicals is not broken down to a finer degree so that one could determine if either cheap electricity or proximity to petroleum refineries or both is of major importance to firms which manufacture chemical products. One is forced to make decisions on a highly aggregated level and any predictions or conclusions that are made will be less reliable than if a finer breakdown was available for this industry.

TABLE 15

MAJOR INPUTS - INDUSTRIAL AND OTHER CHEMICALS

%EI/TI	%PLE/TI	%LI/TI	%KI/TI	%T/TVOP
11.098	6.477	18.796	35.755	3.473
MEI	%MEI/TI	%MEI/EI	MEI/PLE	MEI/T
OPP	5.604	50.576	0.866	1.560

Source: calculated from Dominion Bureau of Statistics, The Input-Output Structure of the Canadian Economy, 1961, Volume 2, Table 13.

When discussing the locational characteristics of the industrial and other chemicals industry one could conclude that transportation is an important factor to consider when choosing a plant location. Capital is quite mobile. Labor is unionized so that there is probably no significant wage differential among different regions of the country.

Energy inputs are important, comprising 11.098 per cent of total input costs of the industry. Other petroleum products (i.e. products of refineries) account for just over one half of these energy inputs. Electricity is the second largest energy input. This is compatible with the above hypothesis that chemical producers would endeavor to locate near cheap electricity or near refineries to gain access to the necessary feedstocks.

The case of industrial organic chemicals is interesting. In Canada there are two major locations for this industry. Edmonton is one, while Sarnia is the other. A sizable petrochemical industry sprang up in Edmonton in the early 1950's. Edmonton was the logical location since it was situated near vast petroleum deposits. A few years later the Interprovincial pipeline was built, facilitating the cheap, efficient movement of crude oil across the country. It enabled firms to set up petrochemical plants near the large Ontario market. A new, large refinery in Sarnia could now provide the necessary feedstock. In addition economies of scale are important to the petrochemical industry. Therefore large plants that could produce ethylene and similar products were established near Sarnia.

Thus, the focus of the industry shifted from Edmonton to Sarnia. The increased costs incurred by transporting crude oil from Alberta to Ontario were more than offset by locations near large Ontario markets which provide agglomeration economies as well as reducing transportation costs on the final product.

As far as industrial inorganic chemicals are concerned their location is not restricted to two main locations in Canada as is the case with organic petrochemicals. Electricity is extremely important in the manufacture of acids, salts and alkalis. Therefore it is not surprising that a preponderance of the firms in the industry are located in Quebec, Ontario and British Columbia.[20] This reflects two things. One is a desire to locate establishments near readily available electricity. The other is to be located near large markets so as to minimize transportation costs.

In the case of other chemicals such as fertilizers transportation would again be important. Transportation costs would be too high and the value of the product too low to make it economically feasible to produce at just a few locations in the country.

It can be concluded that transportation is a significant factor with respect to the location of the industrial and other chemicals industry. Energy inputs are also of extreme importance. Generally it is some tradeoff between the two factors that determines the ultimate location of firms in this industry.

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[20]Dominion Bureau of Statistics, Manufacturers of Industrial Chemicals, 1967, p. 2.

Summary and Conclusions

The determining of the energy intensive industries in Canada was arrived at chiefly by referring to publications of the Dominion Bureau of Statistics, principally the 1961 Input-Output Tables and the individual industry reports of the Census of Manufactures. The Input-Output Tables give breakdowns by energy sources but not by provinces. The Census of Manufactures gives breakdowns by provinces but not by individual energy inputs and there seems to be no satisfactory method for reconciling these deficiencies.

Of twenty industries which could be considered as being energy intensive twelve obviously have an immobile natural resource as their chief locational attraction. Even among these twelve, other influences such as cheap electricity can be important enough to influence the choice between two or more sites. This is the case for pulp and paper mills and for several of the mining industries.

Transportation costs are important for each industry. For some they are significant enough so that the industries in question (cement and lime, clay stone and refractory products) are characterized by a pattern of regional and local markets.

Two industries are probably footloose, no factor having enough of an influence on the industry to determine its location. These are the plastics and synthetic resins industry and the other nonmetal mineral products industry.

In short, it seems that cheap energy will be a significant determinant of industrial location if energy inputs are a large segment of total input costs, if there are few weight losing raw

materials, if transportaion costs are not increased by more than the savings in cost from moving from a low transportation cost site to a low energy cost site and if the energy inputs used are not substitutable for one another.

CHAPTER IV

THE LOCATION OF THE ENERGY INTENSIVE INDUSTRIES

Having determined which of the industries in the 1961 Input-Output Table are energy intensive and having hypothesized what are the locational characteristics of these industries, an attempt will be made to determine if these hypotheses hold for the Canadian case.

The Optimal Approach

The simplest and probably the most accurate method of determining the influence of low cost energy on industrial location is to observe the prices of different energy resources in the various regions of the country and to see if the greatest proportion of firms in a particular energy intensive industry locate near the site where the energy input that is required is cheapest. For instance, one might expect that a firm requiring significant amounts of natural gas as an input would locate in Alberta rather than in Quebec. One could decide if this was actually the case by observing the number of firms in the particular industry that locate in each province and also by noting the number of workers that the industry employs in each province. This type of data is available, for most industries, from the Dominion Bureau of Statistics.[1]

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[1] See: Dominion Bureau of Statistics, Industry Division, Annual Census of Manufacturers for this information.

Obstacles to the Optimal Approach

Although the approach of observing interregional price differentials to determine whether or not the location of the energy intensive industries corresponds to the low price energy locations in Canada is obviously an excellent way to determine how closely the theory corresponds to reality, one runs into difficulties when one tries to determine the actual prices of energy resources in different regions.

One difficulty concerns the definition of a region. In a country that is as geographically large as is Canada some breakdown of provinces into regions such as southern Ontario, northeastern Quebec, southeastern British Columbia, central Alberta and so on is desirable. In Canada, however, data on such variables as employment and output by industry is broken down on a provincial basis only. Thus, statistical sources will hinder this study by providing a less fine breakdown of regions than is optimal.

Another deficiency concerning the data is that the prices of energy resources are not provided for the various provinces. In fact, with the exception of natural gas, the necessary price data are not available at all. One is forced to fall back on general knowledge or on exact data that exist for only a few provinces.

Given these data restrictions two theoretical techniques will be employed to test the hypothesis that energy intensive industries will locate near an area of an abundant supply of low cost energy. These techniques will be the rank correlation test and the location quotient.

The Rank Correlation Method

The rank correlation coefficient is a nonparametric test that is roughly equivalent to the correlation coefficient of the ordinary parametric test. It is a correlation coefficient calculated for the ranks of variables under study rather than for their numerical values. For example, one might wish to test the relation between the total electric generating capacity of each province and the intensity of energy intensive industries in each province. One lists the provinces and the generating capacity by rank. One then does the same thing for the size of electric intensive industries using employment, value added or some other measurement for a criterion. One then applies the formula:

$$r = 1 - 6\left[\frac{\sum(X_i - Y_i)^2}{n(n^2 - 1)}\right]$$

where n = number of provinces

x_i = generating capacity by rank of province i

y_i = electrical intensive industry by rank in province i

r = rank correlation coefficient

The null hypothesis is that the two variables being tested are independent. If the value of "r" is smaller than the critical value which is given in a table then the hypothesis of independence is

accepted.[2] If the "r" value is larger than the critical value then the null hypothesis of independence is rejected and it is assumed that a correlation exists between the two variables.[3]

The Location Quotient

The second technique which will be used to test the location of energy intensive industries vis a vis the location of cheap energy resources is the location quotient. The location quotient is a means of measuring how specialized an area is in the activity of a particular industry compared to a benchmark area which is usually the national economy. If an area has a high location quotient for the activity of a particular industry then it is implied that the area in question is more specialized than is the country as a whole in the activity of that industry. For our purposes the rationale behind employing the location quotient will be to determine whether or not an energy intensive industry locates where there is a plentiful supply of the particular energy input that it requires.

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[2]Critical values for the rank correlation coefficient can be found in: Paul G. Hoel, Elementary Statistics,(New York: John Wiley and Sons, 1966), p. 334.

[3]It should be noted that the rank correlation is a nonparametric test designed to determine only if there is a zero correlation between the two variables being considered and not to test a postulated value for the correlation coefficient as is the case with a parametric method based on the assumption of a normal distribution.

The formula which will be used to determine the location quotient for a particular industry in a province is as follows:

$$\frac{\dfrac{\text{provincial employment in industry "i"}}{\text{national employment in industry "i"}}}{\dfrac{\text{total employment in province}}{\text{total employment in nation}}}$$

If the value of the location quotient for a province exceeds unity then it is implied that for the industry in question the province is more specialized than is the nation as a whole. Examples of this could be the province of Saskatchewan which would have a high location quotient for agriculture and a very low quotient for commercial fishing. For our purposes though, if an energy intensive industry has a location quotient of more than unity for any province, then an attempt will be made to determine if there exists a cheap, plentiful supply of the energy input that is required by that industry.

Data Sources

To calculate the location quotients for the various energy intensive industries, reference was made to both the 1961 Census of Canada and the Census of Manufactures of the Dominion Bureau of Statistics. The Census of Manufactures publications for individual industries give provincial breakdowns of employment for each particular industry. To measure total employment in each province and in Canada the category "persons with jobs" listed in the Census of

Canada was used. This excluded unemployed persons but presumably included salaried people and wage earners. This appeared to be the most suitable data for which provincial breakdowns were available. "Persons with jobs" is superior to the category "labor force" which includes unemployed persons. A province could have a higher rate of unemployed persons than the national average and by using labor force as the measure of total employment the value of the location quotient for any industry would be biased downward for that province.

"Persons with jobs" is also superior to "wage earners" as a measure of total employment. "Wage earners" does not include self employed. In this case a province with a higher proportion of self employed than the national average would have its location quotient for any particular industry biased downwards.

Location Quotients of Energy Intensive Industries

Having set out the framework for the tests, the next step is to proceed with the testing of the location of energy intensive industries vis a vis the location of cheap energy sources. For each energy intensive industry for which there are sufficient data available on a provincial basis location quotients were calculated for each province. This has been done in the following table.

TABLE 16

QUOTIENTS FOR VARIOUS ENERGY INTENSIVE INDUSTRIES

Pulp and Paper Mills	
Newfoundland	2.8157
Nova Scotia	0.5176
New Brunswick	2.3497
Quebec	1.5072
Ontario	0.8341
Prairies	0.1076
British Columbia	1.6398
Industrial Chemicals	
Maritimes (incl. Newfoundland)	0.1005
Quebec	0.9695
Ontario	1.8070
Manitoba-Saskatchewan	0.0927
Alberta	1.0610
British Columbia	1.1477
Plastics and Synthetic Resins	
Quebec	1.8942
Ontario	0.8508
Alberta	1.9452
British Columbia	0.2250

Sources: calculated from Dominion Bureau of Statistics, 1961 Census of Manufactures and 1961 Census of Canada.

Pulp and Paper Mills

In the case of pulp and paper mills the results are not unexpected. The location quotients for Newfoundland, New Brunswick, Quebec and British Columbia all exceed unity. Each of these provinces possesses plentiful forest reserves, the most essential input into that industry. Furthermore, in each of these provinces there exist large electricity generating stations which are owned by the companies operating the pulp and paper mills.[4] Presumably these installations exist near sizable blocks of land but it was probably the potential for installing these stations near the particular blocks of land that induced the companies to locate where they did in the first place. Thus the pulp and paper industry would seem to be an energy intensive industry for which the chief energy input, electricity, can be made readily available with close proximity to the single most important input, an immobile natural resource. If two areas of forest, roughly equivalent in quality and with approximately equal transportation costs to the market, are available to a firm it seems reasonable to expect that the firm would choose that site where the costs of generating electricity would be cheaper. Thus, to some degree, the availability of low cost power will

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[4]For the number, size, location and ownership of these generating stations see: Canada, Department of Northern Affairs and Natural Resources, Electric Power in Canada, 1964, pp. 105-114.

influence the location of firms in the pulp and paper industry.

Industrial Chemicals

For the category manufacturers of industrial chemicals, Ontario, Alberta and British Columbia have location quotients that exceed unity and Quebec is very close to that figure. This industry group includes those establishments manufacturing inorganic chemicals (acids, salts and alkalis) or those engaged in the manufacture of industrial organic chemicals by chemical processes. As suggested earlier, inorganic chemicals, if produced by an electrolytic process, require substantial inputs of electricity. Organic chemicals, on the other hand, require feedstocks of petroleum and natural gas. For the latter category one might expect that firms would seriously consider locating in Alberta where they would be close to the required feedstock. The location quotient for Alberta exceeds unity which would seem to bear this out.

The fact that in 1961 the cost of petroleum feedstocks and of natural gas (used as an input into the production process, not as a fuel) was $33,389,000, whereas the total cost of materials and supplies (i.e. physical goods) used by the industrial chemicals industry was $190,967,000, indicates that the price of these inputs is of major importance to this industry.[5]

Although Alberta has plentiful supplies of petroleum and of natural gas which could be used as a feedstock for the industrial

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[5]Dominion Bureau of Statistics, Annual Census of Manufactures, Manufacturers of Industrial Chemicals, 1962, p. 9.

chemicals industry, both Ontario and British Columbia have higher location quotients for this industry than does Alberta. One reason might be that the production of inorganic chemicals does not require vast quantities of these feedstocks. Another reason could be that when organic chemicals are being considered the required petroleum feedstocks can be produced from any refinery. Technically it would be possible to produce chemicals such as ethylene at a plant situated near Sarnia as easily as at an Edmonton location. The fact that economies of scale are important to this industry would induce firms to locate near the larger Ontario market.

Another factor which causes industrial chemical plants to locate in Ontario rather than in Alberta is the technology of the petroleum industry. It is less expensive to ship the crude oil by pipeline than it is to transport the refined products. Thus refineries locate near large markets and organic chemical plants locate near large refineries. The direct implication of this is that although substantial energy inputs are required by the industrial chemicals industry their nature is not such as to influence firms in the industry to locate near the source of these energy inputs.

Plastics and Synthetic Resins

The plastics and synthetic resins industry has location quotients that are high for Quebec and for Alberta. This means that these two provinces have a higher proportion of total workers employed in this industry than do the other provinces. That the location quotients for Quebec and Alberta are high is not surprising since both provinces

produce many of the chemical inputs that are required by this industry.

The results of the location quotient approach are not unexpected for any of the energy intensive industries under study. For each of the three industries the provinces that one would expect to be specialized in the activities of these industries, relative to the other provinces, are, in fact, more specialized. For the remaining energy intensive industries data were not available for enough provinces to make any test worthwhile. Because of confidentiality regulations and so on, data were not released for provinces having just a few establishments for any industry. In the case of several industries these data restrictions made it impossible to calculate location quotients for the various provinces. It should also be remembered that while the location quotient tells which provinces are specialized in the activities of different industries it remains the task of the analyst to explain why this is so.

Rank Correlation Approach

The other theoretical technique which will be employed to test if there is a correlation between the location of an energy resource and the location of an energy intensive industry is the rank correlation. As stated earlier, it is a nonparametric test which is designed to show only if there is a zero correlation between the two variables under study.

Ideally, the two variables would be the prices of different energy resources in each region and the relative size of firms of

that industry in each region. Data restrictions are such, however, that prices are available, on a provincial basis, for natural gas only. Because of these data restrictions, modifications to the approach must be made. To measure the correlation between the location of electricity inputs and electrical intensive industries rankings were taken for the electric generating capacity of each province and for the value of shipments of goods of own manufacture by firms in energy intensive industries for each province. The category "value of shipments" is a measure of the productivity of the industry. It is a better measure than is employment in that labor may exhibit different levels of productivity in different provinces while value of shipments is an adequate measure of the output of an industry in each province.

To test the relation between the price of natural gas for industrial use and the location of energy intensive industries a rank correlation test was made for the rankings by price (lowest price = 1) and the value of shipments.

In the case of energy intensive industries and the location of oil refineries rank correlations were done for the level of refinery production in a province and the value of shipments of different energy intensive industries for that province. Presumably industries which require substantial inputs of petroleum products would locate near refineries.

With this approach, as with the location quotient approach, sufficient data are available for only a few energy intensive

industries. Thus, only the pulp and paper, industrial chemicals, and plastic and synthetic resins industries can be observed.

Electric Generating Capacity and Energy Intensive Industries

Pulp and Paper Mills. One would expect that a positive correlation would exist between the electric generating capacity of the various provinces and the value of shipments of the pulp and paper industry for those provinces. The fact that the industry accounts for one fifth of the electric energy consumed in Canada would reinforce this opinion.

TABLE 17

ELECTRIC GENERATING CAPACITY AND VALUE OF SHIPMENTS BY RANK FOR PULP AND PAPER MILLS

Generating Capacity		Value of Shipments
5	Newfoundland	5
7	Nova Scotia	7
6	New Brunswick	4
1	Quebec	1
2	Ontario	2
4	Prairies	6
3	British Columbia	3

Rank correlation coefficient = 0.857

Sources: Canada, Dominion Bureau of Statistics, Annual Census of Manufactures, The Pulp and Paper Industry, 1961 and Department of Northern Affairs and Natural Resources, Electric Power in Canada, 1964.

The rank correlation coefficient of 0.857 for pulp and paper mills suggests that at the five per cent significance level there is a positive correlation between the electric generating capacity of a province and the value of shipments of the pulp and paper industry in that province. This does not hold at the one per cent level of significance, however. One could conclude that there is some degree of dependence between the availability of electric power and the location of firms in the pulp and paper industry. As was indicated earlier, the fact that many pulp and paper companies own generating stations emphasizes the importance of cheap and readily available electricity as a factor influencing the location of firms in this industry.

Industrial Chemicals. In the case of industrial chemicals power inputs are important in the manufacture of inorganic chemicals. Thus a positive correlation between the electric generating capacity of a province and the value of shipments of the industrial chemicals industry would not be too surprising.

TABLE 18

ELECTRIC GENERATING CAPACITY AND VALUE OF SHIPMENTS BY RANK FOR THE INDUSTRIAL CHEMICALS INDUSTRY

Generating Capacity		Value of Shipments
5	Maritimes	6
1	Quebec	1
2	Ontario	2
4	Manitoba-Sask.	5
6	Alberta	4
3	British Columbia	3

Rank correlation coefficient = 0.829

Sources: Dominion Bureau of Statistics, Annual Census of Manufactures, The Industrial Chemicals Industry, 1961 and Department of Northern Affairs and Natural Resources, Electric Power in Canada, 1964.

The rank correlation coefficient of 0.829 for the industrial chemicals industry indicates that at the five per cent significance level there is a correlation between the generating capacity of a province and the value of shipments from that province. This is not surprising in that inorganic chemicals usually require an electrolytic process for their manufacture. Based on this knowledge one could conclude that the correlation is more than just association.

Plastics and Synthetic Resins. The third energy intensive industry under study, plastics and synthetic resins has been hypothesized as being fairly footloose with respect to its location although agglomeration economies provided by chemical plants can

have some locational influence.

TABLE 19

ELECTRIC GENERATING CAPACITY AND VALUE OF SHIPMENTS BY RANK FOR THE PLASTICS AND SYNTHETIC RESINS INDUSTRY

Generating Capacity		Value of Shipments
1	Quebec	1
2	Ontario	2
4	Alberta	3
3	British Columbia	4

Rank correlation coefficient = 0.800

Sources: Dominion Bureau of Statistics, Annual Census of Manufactures, Manufacturers of Plastic Resins, 1961 and Department of Northern Affairs and Natural Resources, Electric Power in Canada, 1964.

Again there is a positive correlation at the five per cent significance level. Electric power, however, is too small a proportion of total inputs to directly influence the location of firms in the plastics and synthetic resins industry. Instead the association can be explained as location due to agglomeration factors caused by the industrial chemicals industry, an industry whose location is influenced by the availability of electric power.

Natural Gas Prices and Energy Intensive Industries.

In the case of those industries for which natural gas is a significant input one would expect that interregional price differentials for this energy resource would play a significant role in the

locational decisions of firms in those industries. There are substantial differences in the price of natural gas among the provinces as the following table will show.

TABLE 20

PRICES OF NATURAL GAS (BY PROVINCE) FOR INDUSTRIAL USE 1963-1968

	Dollar Cost per 1000 Cubic Feet					
	1963	1964	1965	1966	1967	1968
Quebec	0.49	0.49	0.55	0.56	0.64	0.55
Ontario	0.54	0.59	0.56	0.60	0.57	0.56
Manitoba	0.33	0.32	0.32	0.32	0.31	0.30
Saskatchewan	0.23	0.25	0.25	0.24	0.26	0.25
Alberta	0.17	0.18	0.18	0.18	0.19	0.18
British Columbia	0.46	0.39	0.39	0.39	0.40	0.36

Source: Canadian Gas Association, Canadian Gas Facts, 1969.

As Table 20 indicates there is a wide discrepancy among the provinces in the price of natural gas for industrial use. The cost in Ontario is more than three times the cost in Alberta. This is not surprising since most of the major Canadian natural gas fields are located in Alberta.

Given these prices for natural gas one would expect that, other things being equal, firms which require substantial inputs of natural gas would locate in Alberta rather than in Ontario. This is not actually the case however. In 1969 41.3 per cent of natural gas sales for industrial use occurred in Ontario compared

with 27.5 per cent in Alberta.[6] In 1970 the respective figures were 45.7 per cent for Ontario and 27.5 per cent for Alberta.[7] This suggests that firms in some industries which require natural gas would rather locate near a large Ontario market than establish a plant in Alberta and incur increased transportation costs. This hypothesis is tested in the following tables which rank the price of natural gas and the value of shipments for the same energy intensive industries that were examined in the case of electricity. Again the year 1961 was the point in time that was considered. The pulp and paper industry was not tested as natural gas is not an important input into the industry and therefore would exert no locational influence.

Industrial Chemicals. As far as the industrial chemicals industry is concerned one would expect that cheap natural gas could influence the location of firms in that industry. One can apply the rank correlation technique to test this hypothesis.

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[6]Canadian Gas Association, Statistical Summary - 1970 (Don Mills: 1971), p. 9.

[7]Ibid., p. 9.

TABLE 21

NATURAL GAS PRICES AND THE INDUSTRIAL CHEMICALS INDUSTRY

Prices		Value of Shipments
4	Quebec	1
5	Ontario	2
2	Manitoba-Sask.	5
1	Alberta	4
3	British Columbia	3

Rank correlation coefficient = - 0.800

Sources: Dominion Bureau of Statistics, Gas Utilities, 1961 and The Industrial Chemicals Industry, 1961.

In the case of the industrial chemicals industry there is no correlation between the price of natural gas in a province and its level of production. This would imply that natural gas is not a major input into the industrial chemicals industry. This is indeed the case. In 1961 natural gas inputs into the industrial and other chemicals industry cost 1.2 million dollars compared to 35.1 million for other petroleum products.[8]

Plastics and Synthetic Resins. If the location of the industrial chemicals industry is not significantly influenced

[8]Dominion Bureau of Statistics, The Input-Output Structure of the Canadian Economy, 1961, Volume 2, Table 13, pp. 65 and 68.

by the price of natural gas then one would not expect that the location of the plastics and synthetic resins industry would be influenced by cheap natural gas. In 1961 natural gas inputs cost only one tenth of a million dollars while the category of other petroleum products accounted for 2.9 millions.[9]

The fact that natural gas prices are not too important to this industry is also borne out by a rank correlation test.

TABLE 22

NATURAL GAS PRICES AND VALUE OF SHIPMENTS BY RANK FOR THE PLASTICS AND SYNTHETIC RESINS INDUSTRY

Prices		Value of Shipments
4	Quebec	1
3	Ontario	2
1	Alberta	3
2	British Columbia	4

Rank correlation coefficient = - 0.600

Sources: Dominion Bureau of Statistics, Gas Utilities, 1961 and The Plastic Resins Industry, 1961.

The results of Table 22 indicate that, as hypothesized, there is no correlation between the price of natural gas in a province and the level of production of the plastics and synthetic resins industry in that province.

[9] Ibid., pp. 65 and 68.

The immediate conclusion that one reaches when analyzing Tables 20 to 22 is that, although there are vast price differentials among the provinces, the price of natural gas is not a significant determinant of industrial location. This conclusion is supported by reference to the 1961 Input-Output Tables which show that for none of the energy intensive industries was natural gas the largest energy input in terms of its costs.[10] It must be emphasized, however, that this was the situation in 1961. Since then industrial consumption of natural gas in Canada has increased threefold.[11]

Petroleum Refineries and the Location of Energy Intensive Industries

Unlike natural gas, petroleum products are a major energy input into some of the energy intensive industries. For those industries it would seem that location near a petroleum refinery would be desirable. For instance, both the industrial chemicals and plastic resins industries require substantial inputs of petroleum products. The following rank correlation tests will determine if there is any correlation between the level of refinery production in a province and the location of firms in these two industries. The pulp and paper industry was not tested as petroleum inputs are an insignificant proportion of the total inputs of that industry.

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[10] Ibid., Table 13.

[11] Canadian Gas Association, op. cit., p. 2.

Industrial Chemicals. In the case of industrial chemicals one might expect that there would be a positive correlation between the level of refinery production in a province and the value of shipments from that province. For example it can be observed that the largest chemical plant in Canada is located at Sarnia near the largest petroleum refinery in Canada.

TABLE 23

REFINERY PRODUCTION AND VALUE OF SHIPMENTS BY RANK FOR THE INDUSTRIAL CHEMICALS INDUSTRY

Refinery Production		Value of Shipments
3	Maritimes	6
1	Quebec	2
2	Ontario	1
4	Manitoba-Sask.	5
5	Alberta	4
6	British Columbia	3

Rank correlation coefficient = 0.600

Sources: Dominion Bureau of Statistics, Refined Petroleum Products, 1961 and Census of Manufactures, The Industrial Chemicals Industry, 1961.

The rank correlation coefficient of 0.600 for the industrial chemicals industry suggests that there is no correlation between the value of shipments of that industry and the level of refinery production. The best explanation that can be offered for this result is that in many cases the data are somewhat imperfect in that for several industries, some provinces, for example the Maritimes,

are grouped together for purposes of the individual industry reports. This may bias the results as several provinces may have a low combined value of total shipments (this is the reason that they are grouped together in the first place) but have a combined total of refinery production that is higher than that of any single province except Quebec or Ontario whose production figures are extremely high. This factor may be enough to destroy any value that might be derived from employing the rank correlation technique.

Plastic Resins. For this industry one might expect that the results would be similar to those obtained for the industrial chemicals industry as the plastic resins industry tends to locate near that industry.

TABLE 24

REFINERY PRODUCTION AND VALUE OF SHIPMENTS BY RANK FOR THE PLASTIC RESINS INDUSTRY

Refinery Production		Value of Shipments
1	Quebec	1
2	Ontario	2
3	Alberta	3
4	British Columbia	4

Rank correlation coefficient = 1.000

Sources: Dominion Bureau of Statistics, Refined Petroleum Products, 1961, and Annual Census of Manufactures, Manufacturers of Plastic Resins, 1961.

The rank correlation coefficient indicates that there is an association between the value of shipments for the plastic resins industry from any province and the level of refinery production for that province. This association is unlikely to be too strong as petroleum products comprise only 2.743 per cent of total input costs of this industry.[11] Most likely it is the fact that large chemical plants exist in the four provinces in which the firms in the plastic resins industry are located that determined the location of firms in the plastic resins industry. Thus any effect of the availability of energy resources as a determinant of location of the plastic resins industry is indirect.

Summary and Conclusions

Empirical techniques were employed in an attempt to determine if the hypotheses developed in previous chapters corresponded with the actual pattern of location of the energy intensive industries in Canada. The concepts of location quotients and rank correlations were applied to three industries which could be considered as being energy intensive.

The results yielded by the location quotients did not deviate to a significant degree from what one would expect in terms of the level of specialization of different provinces in these industries. The chief value of the location quotient is that it shows whether

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[11] See Table 14, p. 59, this study.

or not a province is specialized in the activities of a particular industry. It is up to the analyst to determine why the particular province is or is not specialized.

The device of employing rank correlation tests to determine if there is a relationship between the existence of a particular energy resource and the level of production of various energy intensive industries in a province yielded less satisfactory results. As expected, electricity was important to the pulp and paper industry. There was also a positive correlation between electricity generating capacity and the level of production of the industrial chemicals industry. This is because many types of industrial inorganic chemicals use an electroytic process in their production.

The price of natural gas seemed to have no bearing on the location of any of the three industries. This is not surprising as natural gas was not the largest energy input of any of the energy intensive industries.

The surprising result of the tests is that proximity to petroleum refineries does not appear to be too important to the industrial chemicals industry. One would qualify the results of the rank correlation tests by referring to imperfections of the data used. Figures for many industries are grouped together by provinces or groups of provinces and such groupings can invalidate the data for purposes of testing by rank correlation.

In essence, it seems that the chief value of using theoretical tools such as location quotients and rank correlations is that it

forces the analyst to explain just why the particular results that are obtained do or do not correspond to the postulated hypotheses that have been developed.

CHAPTER V

LINKAGE EFFECTS AND ENERGY INTENSIVE INDUSTRIES

To this point consideration has been given to the theory of location of firms with particular emphasis being placed on those firms in the energy intensive industries. Attempts were made to relate the location of firms in the energy intensive industries to the location of their most important energy inputs.

This chapter will deviate somewhat from the approach taken in previous chapters. An effort will be made to determine how certain energy intensive industries affect the location of associated industries through agglomeration economies. The means of determining this will be the concept of linkage effects.

Linkages Defined

There are two types of linkages: forward linkages and backward linkages. An industry which sells part or all of its output to other industries is said to possess forward linkages. It is said to possess backward linkages if it purchases its inputs from other industries. For example, the industrial organic chemicals industry would be backward linked to the petroleum products industry, a supplier of inputs to the chemicals industry.

The existence of a firm in an industry which has substantial forward or backward linkages, or both, could provide an incentive for firms of linked industries to locate in the same area as the firm of the first industry. In other words, the existence of a firm possessing forward or backward linkages can induce agglomeration in an area.[1] One example is the steel industry which can draw in many firms for which steel is an essential input. While such agglomeration activities could take place they do not always occur. Other locational factors may be such that an industry may not locate within physical proximity to the industry to which it is linked. An example of this is the petroleum industry which transports crude oil by pipeline to the market rather than refining the product near the source of supply. It is important to keep in mind the fact that even though some activities may not cause agglomeration near the source of supply, they may, through their linkage effects, be important for national growth and development.

Hirschman places more importance on the existence of backward rather than forward linkages as a development mechanism.[2] The industry with backward linkages induces the establishment of firms to supply the industry with its inputs. For forward linkages to become effective there must be a demand for the final product. Hirschman

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[1]For a discussion of the framework of agglomeration economies see Chapter II, pp. 14-16.

[2]Albert O. Hirschman, The Strategy of Economic Development, (New Haven: Yale University Press, 1954), pp. 116-117.

says that "...forward linkage could never occur in pure form. It must always be accompanied by backward linkage which is the result of pressure of demand. In other words, the existence or anticipation of demand is a condition for forward linkages to manifest themselves".[3]

If an industry with substantial backward linkages induces investment and a forward linked industry has the potential to do the same then an industry possessing both forward and backward linkages should provide an even greater potential for economic growth and development, in that it could induce the establishment of firms which could supply it with its inputs as well as influencing the choice of where prospective purchasers of its output would set up a plant. In effect such an industry could be termed a "key" industry. Its linkage effects, if exploited to their full potential, could lead to the rapid economic development of an area if the linkages occurred in that area.

The objective of this chapter will be to determine which of the energy intensive industries are backward linked, forward linked or both. An examination will also be made of the energy resources and their linkage effects.

Measurement of Linkage Effects

In order to determine just which industries are forward linked, backward linked or both, some means to measure the extent of these linkages must be employed. Chenery and Watanabe use indices measuring

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[3] Ibid., p. 116.

"indirect use" and "indirect demand".[4] The first of these concepts can be expressed as a ratio of the purchases of one sector from all other sectors to the total value of production. This ratio can also be termed "intermediate use" and its value is a measure of the backward linkage effect of a sector of the economy.

The second concept, that of indirect demand, is a ratio of the total purchases of all other sectors from the sector under consideration to the total value of demand for the products of that sector. This "indirect demand" can be used as a measure of the forward linkage effect of a sector.

In addition to indirect use and indirect demand there exist measures of the intensity or dispersion of the linkage effects of an industry to the rest of the economy.[5] A linkage effect would be intense if the industry in question was linked primarily to just one or two other industries. An industry's linkage effects would be dispersed if they extended to several other industries. For example the forward linkages of the iron and steel industry would be dispersed as a great number of industries rely on the iron and steel industry for inputs. The backward linkages of the utilites would be intense

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[4] H. Chenery and T. Watanabe, "International Comparison of the Structure of Production", Econometrica, XXVI, (October, 1958), pp. 487-521.

[5] See D. Sakellariou, A Comparative Study of Industrial Characteristics Important for Economic Development, unpublished draft dissertation, University of Alberta, pp. 98-124, for a precise interpretation of these measures.

since the input requirements of this industry do not extend to many other sectors of the economy.

Employing the basic concepts of input-output analysis Sakellariou applied measures of the intensity or dispersion of linkage effects.[6] Backward linkages were represented by

$$D_j = \frac{\frac{1}{n} Z_j}{\frac{1}{n^2} \sum Z_j}$$

where Z_j represents the direct and indirect output that must be supplied, on the average, by any one industry due to an increase in final demand for the product of industry j. If D_j exceeds unity then it is implied that industry j relies on many industries for its inputs. A D_j value of less than unity implies that industry j draws on fewer industries than the average for its inputs.

With respect to forward linkages, the measure of dispersion used by Sakellariou is

$$S_i = \frac{\frac{1}{n} Z_i}{\frac{1}{n^2} \sum Z_i}$$

where Z_i represents the amount an industry i would have to increase

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[6] Ibid., p. 28.

its output due to an increase in final demand of another industry chosen completely at random. An S_i value exceeding unity implies that many industries rely on industry i for their inputs. A value of less than unity implies that few industries rely on industry i for inputs.

Problems of the Data

Attempting to make intertemporal comparisons of intersectoral relationships, Sakellariou aggregated the Canadian Input-Output Tables of 1949 and 1961 to a 38 x 38 size. The chief problem that is encountered here is the level of aggregation to which the table has been taken. It could happen that an industry would purchase inputs from another industry but because the two industries are listed in the same sector no linkage effect is measured. Even with such limitations, however, the results of Sakellariou's work are useful in that they show how broad sectors of the economy are linked to other sectors.

The following sections of this chapter will use the data gathered from these tables, for the year 1961, to measure the intensity or dispersion of linkages of energy intensive industries and also to determine if the industries are forward linked, backward linked or key industries.

Dispersion of Linkages of Energy Intensive Industries

Knowledge of the intensity or dispersion of the linkage effects of energy intensive industries can be useful in that such knowledge

enables one to predict how many industries would be affected by changes in demand for the products of any of the energy intensive industries.

Table 25 will show the intensity or dispersion of forward and backward linkages of each of the thirty-eight sectors as compared to the average for all sectors. Those sectors shown in the upper half of Table 25 had backward linkages which were dispersed to a greater degree than the average dispersion of backward linkages for all sectors (i.e. their D_j values equalled or exceeded unity). Those on the right hand side of the table had forward linkages which were dispersed to a greater degree than the average (i.e. their S_i values exceeded unity).

According to Table 25 the following energy intensive industries had both intense forward and intense backward linkages: fishing, hunting and trapping; coal mining, crude petroleum and natural gas; non-metal mining, quarrying and prospecting; and primary iron and steel. These particular energy intensive industries had forward and backward linkages with fewer sectors than did the average industrial sector. A change in demand for the products of one of these industries would extend primarily to just a few other sectors. The same applies, of course, to all other sectors in Quadrant IV.

Quadrant III shows those sectors which had dispersed backward but intense forward linkages. Only one energy intensive industry, products of petroleum and coal, was included in this category. This seems somewhat surprising since one intuitively feels that this

TABLE 25

INTENSITY OR DISPERSION OF LINKAGES - 1961

III	II
Meat Products Dairy Products Fish Processing Fruit and Vegetable Processing Grain Mill Products Bakery Products Alcoholic Beverages Tobacco and Tobacco Products Leather Products Clothing Wood Products Transportation Products Products of Petroleum and Coal	Metal Mining and Nonferrous Smelting and Refining Paper Products Agricultural Implements Chemicals and Allied Products Construction Service Industries
IV	**I**
Fishing, Hunting and Trapping Coal Mining, Crude Petroleum and Natural Gas Nonmetal Mining, Quarrying and Prospecting Carbonated Beverages Confectionery and Sugar Refining Furniture Printing, Publishing and Allied Industries Primary Iron and Steel Miscellaneous Manufacturing Electrical Apparatus and Supplies	Agriculture Forestry Textile Products Transportation, Storage and Trade Electricity, Water and Gas Utilities Finance, Insurance and Real Estate

Source: D. Sakellariou, A Comparative Study of Industrial Characteristics Important For Economic Development, unpublished draft dissertation, University of Alberta, p. 142.

industry obtains most of its inputs from the sector of coal mining, crude petroleum and natural gas. In addition it would seem that the industry's output becomes inputs into the production process of many other industrial sectors. This is refuted, however, by the data gathered by Sakellariou.

Quadrant I shows those sectors which had dispersed forward but intense backward linkages. Energy intensive sectors in this category were: agriculture; forestry; and electricity, water and gas utilities. One would expect that these sectors would be included since all three rely on very few industries for their inputs and their output is expected to become inputs for several sectors.

The final quadrant, Quadrant II, shows those industries with dispersed backward and forward linkages. They purchased their inputs from a great many other sectors and also sold their output to be used as inputs for several other sectors. Three sectors in this category could be considered as being energy intensive: metal mining and non-ferrous smelting and refining; paper products; and chemicals and allied products. One might expect that the location of one of these industries in an area could lead to further economic expansion of an area since it could draw in many other industries. Whether or not such a thing would happen would depend on the absolute amounts of outputs of other sectors which would be required by the industry with the dispersed linkages. If the industry required a substantial quantity of the output of an industry to which it was backward linked then it might induce the location of a firm to supply it with this necessary input. Thus, not only the intensity of the linkage but its absolute

size influences location by agglomeration.

It must be emphasized again that any conclusions that might be reached concerning the dispersion of linkages of industries must be qualified by referring to the highly aggregated data which reduces the accuracy of any measurements that are calculated.

Strength of Linkages of Industrial Sectors

The previous section discussed the intensity or dispersion of linkage effects of the energy intensive industries. In addition it would be useful to know the strength of the linkages in relation to those of other sectors of the economy. This was also done by Sakellariou, again using the thirty eight sectors and the year 1961. In the following table all sectors listed in the upper half possessed a measure of indirect use that exceeded the average for all sectors (i.e. they were backward linked). Those listed on the right side of the table had a measure of indirect demand that was higher than the average for all sectors (i.e. they were forward linked).

In Table 26, Quadrant IV indicates those industrial sectors which possess both weak forward and weak backward linkages. Their existence is unlikely to draw other industries into an area, nor is the existence of any specific industry likely to influence where firms of industries in Quadrant IV will locate.

Quadrant III shows those sectors which have strong backward but weak forward linkages. Generally, much of the output of those sectors goes to final demand. The existence of one of those backward

TABLE 26

INDUSTRIAL SECTORS BY TYPE OF LINKAGES - 1961

III	II
Meat Products Dairy Products Fish Products Fruit and Vegetable Preparations Bakery Products Alcoholic Beverages Tobacco Products Leather Products Clothing Paper Products Transportation Equipment Construction	Grain Mill Products Wood Products Agricultural Implements Products of Petroleum and Coal Chemicals Service Industries
IV	**I**
Nonmetal Mining Carbonated Beverages Confectionery and Sugar Refining Furniture Miscellaneous Manufacturing Electrical Apparatus and Supplies Finance, Insurance and Real Estate	Agriculture Forestry Fishing, Hunting and Trapping Metal Mining Coal Mining, Petroleum and Natural Gas Rubber Products Textile Products Printing and Publishing Primary Iron and Steel Nonmetallic Mineral Products Transportation, Storage and Trade Communication Electricity, Water and Gas Utilities

Source: D. Sakellariou, A Comparative Study of Industrial Characteristics Important For Economic Development, unpublished draft dissertation, University of Alberta, p. 105.

linked industries in an area could draw in firms to supply it with its inputs. Conversely, the existence of firms to which the industry is linked could induce that industry to locate in the same vicinity.

Quadrant I is just the opposite of Quadrant III. Its industries have strong forward but weak backward linkages. Most of the output of these industries becomes inputs into the production processes of other industries, while little is purchased from other industries by industries in this quadrant. It is not surprising that a number of industries in this quadrant are classified as primary industries. Furthermore, it is worth noting that a number of energy resources, listed under the headings of coal mining, petroleum and natural gas; and electricity, water and gas utilities, have heavy forward linkages.

Finally, Quadrant II lists those key industries which are endowed with strong forward and backward linkages. These are the industries which draw heavily upon other sectors of the economy for their inputs and in turn provide substantial portions of the inputs of other sectors.

Obviously, the choice of location of these key industries has a heavy bearing on which parts of a country will develop. If they locate near the places of production of the industries to which they are backward linked, then an area which possesses the products needed by these key industries has an excellent potential for economic expansion. If, on the other hand, the key industries do not choose to locate near the sources of these inputs, then, as far as an area possessing these inputs is concerned, the potential economic development

that could arise due to the exploitation of potential forward linkages is unlikely to take place. Thus, the locational characteristics of key industries are of major concern when considering the role that energy or any other input plays in the locational decisions of firms.

Linkages of the Energy Intensive Industries

Based on the thirty eight sectors presented above it is clear that the energy resources are forward linked. This is evident by the fact that two of the sectors in Quadrant I of Table 26 are coal mining, petroleum and natural gas; and electricity, water and gas utilities. Initially one might conclude that an area which possesses some or all of these energy resources could, due to the forward linkages of these resources, attract industries which are heavily backward linked to them (i.e. attract energy intensive industries to the same regions from which energy resources originate). The Canadian experience would suggest, however, that this is not always the case. Essentially this is because energy resources are not weight losing. Hence their processing or refining is at or near the market in order to minimize transportation costs on final products since such transportation costs are higher than those of transporting energy resources. This would seem to suggest as well that the exploitation and processing of energy resources does not have as many linkages or as powerful linkages as do primary manufacturing and secondary manufacturing industries.

According to Table 26 only one energy intensive industry,

nonmetal mining, has both weak forward and weak backward linkages. The existence of such an industry in any area is unlikely to draw in industries to supply it with inputs or to purchase its output.

In Quadrant III of Table 26 (strong backward but weak forward linkages), one energy intensive industry, paper products, appears. It is possible that the location of firms in such an industry could be influenced by the availability of a large input. In previous chapters it was hypothesized that the availability of electricity, a significantly large input, influences the choice between two or more alternative locations.

In Quadrant I (weak backward but strong forward linkages), several energy intensive industries appear. They are: agriculture; forestry; fishing, hunting and trapping; metal mining; primary iron and steel; and nonmetallic mineral products as well as the previously mentioned sectors of coal mining, petroleum and natural gas and electricity, water and gas utilities. That utilities are forward linked is not surprising since by definition they provide a necessary service to residential, commercial and industrial establishments. The services provided are necessary inputs to these establishments.

Because the industries in Quadrant I have weak backward linkages relative to other sectors of the economy it should not be concluded that the location of industries to which they are backward linked does not influence their location. For instance, metal mines must obviously locate at the site of the ore body. Iron and steel mills give much consideration to the location and quality of raw materials

when choosing a plant location. The fact that even though these industries have weak backward linkages and still are influenced in locational decisions by the existence of firms of industries to which they are backward linked should not be surprising. It was mentioned in a previous section of this chapter that most of these energy intensive industries had intense backward linkages. They relied heavily on a small number of industries for their inputs. Because of this the location of one of the industries on which they rely for inputs could influence their choice of location.

Location of Key Energy Intensive Industries

From Table 26 the key industries in terms of their linkage effects are: grain mill products; wood products; agricultural implements; products of petroleum and coal; chemicals; and service industries. Of those six key sectors two, products of petroleum and coal, and chemicals could be considered as being energy intensive.

An examination of the locational characteristics of firms of those two key sectors which are energy intensive can shed some light on the importance of energy resources as a determinant of industrial location. The classification of products of petroleum and coal is quite large and includes a variety of industries. Included are such industries as asphalt roofing, the coke and gas industry and petroleum refineries.[7] Petroleum refineries account for a significant proportion of the size of the sector, whether the unit of measurement

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[7]See Dominion Bureau of Statistics, Standard Industrial Classification Manual, 1951 or 1961 for a description of industries in each sector.

is employment, production or value added.

The technology of the petroleum industry is such that it is less expensive to ship crude oil long distances by pipeline than it is to transport refined products the same distance. Thus, pipelines transport the crude oil from the source of supply to centers of large population to be refined. Therefore, in Canada the largest petroleum refineries are to be found in Sarnia, Toronto and Montreal rather than in Edmonton. This means that much of the forward linkage effect of the petroleum industry is exported from the site of the source (Alberta) to the area in which a key industry is located (Ontario). Presumably, many of the forward linkages of the petroleum refining industry also occur in Ontario. One example is the industrial organic chemicals industry which requires substantial petroleum feedstocks.

The industrial organic chemicals industry is part of the sector listed under chemicals in Table 26. According to the table the chemicals industry is a key industry in terms of its linkage effects. As was mentioned in the preceeding chapter, a large number of establishments are located in Ontario. This could be due partly to a market orientation of these establishments since most of the customers of these industries are located in Ontario. More likely, though, the locational force that draws these firms to Ontario can be explained by a recurrent theme, the existence of large petroleum refineries in Ontario. The ready availability of large feedstocks of petroleum products enables firms to set up plants large enough to capture significant economies of scale.

Apparently economies of scale are important to firms in the chemicals industry. In the production of ethylene, for example, large scale economies are captured at a level of production of one billion pounds per year. This level of production represents the entire domestic demand for the product. It seems that several of the firms in this industry are considering the feasibility of constructing one large plant of this capacity near Sarnia.[8] Among other things, ethylene is an important input into the production of synthetic rubber, polyethylene, antifreeze and gasoline additives. Hence this industry has substantial forward linkages which can be captured by an area in which a large ethylene plant is located. A large plant located at Sarnia could use hydrocarbon feedstocks from western Canada.[9] The essential point to remember, however, is that the forward linkages in terms of production and employment will occur in Ontario and not in Alberta, the source of these feedstocks.

With respect to organic chemicals such as fertilizers there are large plants located both in eastern and western Canada. Large fertilizer plants are located near Edmonton with sufficient capacity to serve the western Canadian market. Because of the bulky nature and low value of the product transportation costs are important and make it impossible for just one location to serve the entire national market.

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[8] The Financial Post, August 21, 1971, p. 1.

[9] Ibid., p. 1.

Summary and Conclusions

It appears that, as far as petroleum and petroleum products are concerned, the linkage effects need not be confined to the area in which the crude oil is discovered. This characteristic would likely be less applicable in the case of electricity which also has heavy forward linkages. Although electricity can be transmitted efficiently in terms of little loss of power, to do so for any great distance becomes expensive. Pulp and paper mills, for instance, require vast inputs of electricity and generally locate near a large generating plant or else establish such a plant near the forest site at which the mill will be located. For other electricity intensive industries, such as mining, the immediate forward linkages are also unlikely to occur in an area other than that in which the electricity originates.

Coal is an energy resource which is easily transportable. Hence most of the forward linkages involved occur outside the area in which the resource is found.

Natural gas is another energy resource which is easily transported by pipeline and thus most of the forward linkages can be shifted away from the area where the natural gas originates.

To sum up this chapter, it can be said that the energy resources considered here all seem to possess substantial forward linkages. Theoretically, the existence of these energy resources in an area could induce industries which have heavy backward linkages with these energy resources to locate near the source of these resources. With the exception of electricity, however, these resources are easily transportable

and therefore the forward linkages do not necessarily occur in the area where the energy resource originates. The conclusion which can be drawn from this is that it is not enough to consider the location of an energy resource. Consideration must also be given to the location of industries which are linked to the energy resources when predicting which areas will experience economic development due to an increase in demand for products of energy intensive industries.

CHAPTER VI

CONCLUSIONS

The objective of this study was to determine the significance, if any, that the pricing of energy inputs plays in the locational decisions of firms. The hypothesis that energy resources, although their use is pervasive throughout the economy, influence the locational decisions of firms in only a few industries seems to be supported.

Although a number of industries can be said to be energy intensive in terms of their inputs, in most cases there is another, more decisive, factor that determines where these firms will locate. Generally, this other factor is an immobile natural resource. The firm has to locate at the site of this resource in order to exploit any economic potential that the resource may offer.

For some industries the price of an energy input may not be the major determinant of where a firm chooses to locate but it is important enough to be a deciding factor in the choice between two or more alternative locations. This might apply to the pulp and paper industry where a firm can choose between two or more roughly equivalent forest sites. The factor that could tip the balance could be the availability of low cost electricity, a major input. This situation could also exist for other energy intensive industries such as mining. A firm could have a choice between several coal mining sites,

for example, and might choose that site which had an electricity transmission line located nearby. These examples indicate that the price differentials of electricity in different areas can influence the locational decisions of firms in certain industries.

Data limitations have made any quantitative measurement of the influence of low cost energy on industrial location exceedingly difficult. Intuitive feelings that price differentials of natural gas in the different regions of Canada have a bearing on where certain types of industry locate are not borne out by referring to the data that are available.

Price data on coal are not particularly useful or plentiful. Probably the most important thing to remember about coal is that domestic production is subsidized but that this production is less than sufficient to meet the demand and thus a significant amount is imported. As well, it should be noted that for several industries coal can serve as a substitute for fuel oil or natural gas. This property of substitutability among energy resources may make price differentials of energy resources in different regions less significant than would otherwise be the case.

Data on petroleum products are also less than satisfactory. Although price data are unavailable, production data shows that refining takes place near large centers of population. The main implication that can be drawn from this fact is that many of the forward linkages of the petroleum industry in Canada occur in Ontario rather than in Alberta. This means that many energy

intensive industries locate in the former province rather than in the latter. This is important to keep in mind when calculating the benefits which might accrue from the possible construction of a pipeline from the Canadian Arctic to the southern portions of this continent. Few future benefits would accrue in terms of long run employment of northerners.

In general, it can be maintained that energy resources play an important role in the economy of a nation. As far as being a decisive factor in the locational decisions of firms, this characteristic would seem to apply to only a few industries. Even for these industries the role of energy inputs is uncertain. In order to better understand the importance of energy in a national economy, consideration should be paid to the linkage effects of energy intensive industries as these effects can extend throughout the economy. Most important to future analysis, however, is the availability of data. Breakdowns of uses of energy resources by industries and by types are required. So, too, are price data for energy resources by region and by type of energy resource used. With the knowledge that could be gained from such data, more precise conclusions could be reached about the importance of the cost of energy inputs as a factor influencing industrial location.

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